Fifteen Years Filtration Practice in Indianapolis

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FIFTEEN YEARS FILTRATION PRACTICE IN INDIANAPOLIS.

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At the time that the experiments on the purification of the Ohio River water were being made at Louisville, Ky., the Indianapolis Water Company called into consultation Mr. George W. Fuller in reference to the development of a filtration system. A brief report was made by him in which it was suggested that studies comparable to the Louisville investigation be carried on at Indianapolis. Allen Hazen made an extended report in July of 1896, recommending slow sand filtration. Between this time and 1902 practically every engineer prominent in the water purification field at that time made a more or less extended report on the purification of water from White River. The committee of the Board of Directors of the Indianapolis Water Company in April, 1902, definitely approved suggestions looking toward the construction of a slow sand filtration plant and the United States Sand Filtration Company was awarded the contract for the construction.

It may be worth while in passing to suggest that the period of 1900-1902 was one when purification projects were also under way in a number of the large cities of the country, notably Philadelphia, Pittsburgh and Washington. The Washington filtration question was investigated by the Corps of Engineers of the United States Army under the direction of Colonel Miller, and while his recommendation was for the construction of a mechanical type plant, such opposition developed in the community led by the Medical Association of the District of Columbia, that the committee of the United States Senate appointed to investigate the question overruled Colonel Miller's recommendations and Washington, like Albany, Philadelphia, Pittsburgh and Indianapolis built a filtration plant of the slow sand type. In all cases these plants have been modified upon the basis of experience following the actual operation of the system. In each case it was found that while the system was able to handle very adequately raw water of normal conditions, any condition of overload, especially as referred to the amounts of suspended matter, was reflected in a corresponding variation in the quality of the finished product together with a very decided lessening of

the output of the plant due to surface or sub-surface clogging of the sand layer.

Due to the relative uncertainty as to the necessities involved in the construction of a filtration plant at Indianapolis, the construction as completed in 1904 represented only the portion of the plant the necessity of which building was beyond doubt. Three filters were constructed, each having an area of 1.6 acres. These were uncovered. The relatively large size and lack of cover was largely brought about by the desire to take advantage of some mechanical method of removing the soiled surface sand. The first unit was completed and put in service on September 23, 1904, the second on November 10th and the third on December 21st. The operation during the first winter indicated beyond question the necessity of covering. It had also been made reasonably clear that the system of mechanical cleaning which had been contemplated would not be satisfactory and that units of the size then constructed were too large. Accordingly, beginning May 30, 1905, the filters were taken out of service in order, a central dividing wall placed in the unit making two of .776 acre each covered with a flat slab roof supported on cast iron columns. This reconstruction was completed by August 7, 1906. The abnormal difficulties due to formation of ice in winter were eliminated and the division into smaller units produced a more even amount of filtered water. During the year following the reconstruction of the plant an average of 11.7 m. g. of water per day was produced, the filters operating at an average of 2.5 m. g. per acre per day. During the year 1908 the average total output was reduced to 8.6 m. g. per day. It became definitely understood by this time that the treatment of White River water in slow sand units without preliminary treatment was producing a considerable deposition of suspended matter in the entire sand layer and that at times when the amount of suspended matter became quite high not only was a certain proportion of this carried through the filter but there was a masking of the biological action within the sand layer which reduced the efficiency of the unit. Investigation of the operating conditions in other cities of the country having plants of the same type indicated that this difficulty was not confined to the local situation, and consideration of the methods which could be used to eliminate the difficulty resulted

in the determination to construct a preliminary settling basin of a capacity approximating 48 hours supply, to the water entering which a coagulant would be applied when the turbidity reached a certain point. The slow sand filtration plant at Poughkeepsie, N. Y., had adopted this method of pre-treatment some years before. The tendency at the Philadelphia plants was to resort to pre-filtration. Later developments at the Washington plant resulted in the adoption of the same method of pre-treatment as was adopted at Indianapolis, and more recent developments at Philadelphia have indicated that even the pre-filtration fails to protect adequately the final sand layer, and at Albany, N. Y., preliminary coagulation is resorted to at times of high turbidity. Following the construction of the settling basin and the chemical house a general cleaning of the sand layer was made and increase in the daily output made ranging 12.5 m. g. for the entire plant in the year 1909 and reaching 20 m. g. in the year ending December 31, 1913.

PRODUCTION SUMMARY.

There is inserted herewith a "Production and Cost Summary" which gives by years the data as to water filtered and total cost of operation, together with certain chronological data which has a bearing upon the productive capacity of the plant:

PRODUCTION AND COST SUMMARY

Year Ending	Million Gallons Filtered	Average Million Gallons per Day	Operation Cost: Total	Operation Cost: Per Million Gallons	Chronological Data
3-31-05	665.800	3.500	$ 9,119.10	13.750	First filter in operation Sept. 22, 1904.
3-31-06	2,772.550	7.600	11,367.60	4.100	Filters divided and roofed.
3-31-07	4,265.910	11.700	16,111.00	3.780	
3-31-08	3,138.870	8.600	18,634.22	5.440	Temporary alum plant installed.
3-31-09	4,565.335	12.500	26,182.84	5.740	
3-31-10	5,708.147	15.600	30,630.26	5.370	Hypochlorite of lime first used. Pre-treatment plant complete.
3-31-11	6,528.772	17.900	28,993.80	4.450	Regular use of Hypochlorite of lime.
12-31-11	5,459.294	19.850	22,375.10	4.100	Use of Copper sulfate as algecide during summer begun.
12-31-12	7,083.319	19.350	30,782.90	4.330	
12-31-13	7,311.339	20.030	28,431.89	3.890	
12-31-14	7,638.786	20.930	25,616.52	3.350	
12-31-15	6,644.384	18.200	26,591.52	4.005	
12-31-16	7,299.157	19.940	28,037.65	3.849	Liquid chlorine used first May 1916.
12-31-17	7,560.215	20.720	37,178.14	4.919	
12-31-18	8,131.824	22.289	41,207.02	5.068	
12-31-19	8,719.711	23.890	39,565.51	4.538	
Averages:					
Sept. 1904–Mar. 1909		9.327	....	5.280	1,652 days—15,408.465 M. Gals. filtered.
Apr. 1909–Dec. 1919		19.883	....	....	3,927 days—78,082.570 M. Gals. filtered.
Jan. 1915–Dec. 1919		21.000	....	4.50	1,726 days—38,355.291 M. Gals. filtered.

During the first five years of the operation of the Indianapolis filters an average of 9.3 m. g. per day was produced. During the five years ending December 31, 1919, an average of 20.8 m. g. per day was produced. The output in 1919 amounted to 8,718,000,000 or an average daily of 23.82 m. g. The first five years of operation, which consisted in filtration and laboratory control only, cost an average of $5.28 per m. g. produced. The five years operation ending December 31, 1919, included additional charge for pre-treatment and sterilization and the average cost per million gallons produced was $4.50. This expense is divided as follows:

	Laboratory	Pre-treatment	Filtration	Grounds	Total
Labor	$ .553	$ .135	$1 038	$ .207	$1.933
Supplies	.265	Alum 1.395 Chlorine .252	.324	....	2.236
Maintenance:					
Equipment	.061	.050	.085	....	.196
Buildings	.010	.035	.09	....	.135
Total	$ .889	$ 1.867	$ 1.537	$ .207	$4.500
% of total	19.7	41.5	34.2	4.6	....

The improvement in operating conditions as evidenced by the reduction in expense and increased output is the result of ability to produce a larger quantity of water per operating day and the handling of a smaller amount of sand per million gallons produced. The operation of the slow sand filter plant consists essentially of one item, that is, the maintenance of the sand layer in a condition that will produce the maximum amount of purified water per yard of material handled. The data as to filter unit operation is shown in Table I.

TABLE I

OPERATION DATA FOR ALL FILTERS ON RUNS COMPLETED DURING YEARS NOTED

Year	Number of Filter Runs	Total Days Service All Units	Average Number of Days per Run	Total Produced Mil. Gals.	Total produced per Filter Run per Acre Mil. Gals.	Average Rate per Day per Acre	Cubic Yards Sand Scraped	Cubic yards per million Gallons Produced
1904	1	52.	52.	49.000	63.100	1.21	....	....
1905	18	869.8	48.3	1,248.000	89.400	1.85	....	....
1906	64	1,742.	27.2	3,547.000	71.500	2.63	....	....
1907	85	2,025.45	23.9	3,960.000	60.000	2.5	....	....
1908	70	1,771.16	25.3	3,400.000	62.600	2.5	....	....
1909	59	1,911.	32.4	5,420.000	118.400	3.65	....	....
1910	73	2,007.95	27.5	6,140.000	108.400	3.98	....	....
1911	74	1,978.9	26.7	6,910.000	120.300	4.50	....	....
1912	78	2,065.8	26.5	7,120.000	117.600	4.44	....	....
1913	57	1,959.6	34.4	7,095.000	160.600	4.67	6,307	0.900
1914	72	2,104.2	29.2	7,974.400	143.000	4.9	7,923	0.990
1915	61	1,992.2	32.7	6,415.200	135.500	4.11	6,678	1.040
1916	49	1,817.4	37.	7,013.500	184.700	5.	5,671	0.810
1917	54	1,932.9	36.	7,471.200	180.600	5.	6,466	0.866
1918	53	1,960.9	37.	8,420.320	204.700	5.53	6,414	0.760
1919	44	1,882.7	42.8	8,430.150	247.200	5.78	6,307	0.705

Note:—Figures in this table refer to filter runs completed during various years and do not check with meter or delivery totals for natural year.

In the years preceding the adoption of the pre-treatment process the average number of days a filter would run before needing cleaning approximated 25 and the average output per acre of sand surface 62.5 m. g. At the close of these runs the removal of sand necessary to place the unit in satisfactory operating condition for the succeeding run averaged 2.5 cubic yards per m. g. of water produced. The improvement in the quality of the water entering the filters has been manifested during the past five years by an increase in the number of days run between cleanings to 42.8 and an average million gallons produced between cleanings of from 135 in 1915 to 247.2 per acre in 1919, and whereas the average running rate per day in 1906, 1907 and 1908 averaged 2.5 the running rate in 1916 and 1917 was 5 m. g. per acre per day and in 1919, 5.94. At the same time the necessity of removing 2.5 yards of sand per million gallons of water filtered, has been reduced to approximately 1 yard in 1913-14-15 and .705 yard in 1919. These results of the improved character of the water entering the filters are of course intimately correlated. The reduction in the amount of sand handled per yard is directly proportional to the amount of material which the filter is compelled to remove and the condition of this material as to the ability of the filter to remove it immediately at the sand surface or fractions of an inch below. The reduction in the amount of sand removed also obviously reduces the amount of time which the filter must remain out of service for cleaning and sand restoring purposes. The reduction in this amount of lost time then increases the available running time of the unit and the total output of the plant.

Tables II, III and IV show for the life of the plant by months the total daily production, daily acre rate and per cent time lost. While there is an apparent increase in the lost time during the past three years, the increase is due to the standing idle of filter units because the pumping department could not store the water as it was filtered, and not to any necessities of the filter plant itself.

Beginning with 3 large open filters in 1904, the results of operation as to quantity produced and efficiency of operation fell below the criterion established by such plants as that at Lawrence, Mass. When this difficulty was recognized and the units divided and covered and the preliminary coagulation

sedimentation processes added, the quantity and quality efficiencies of the plant showed a satisfactory increase. A rate of approximately 4 million gallons per acre per day was attained in 1910, an amount which fully justified the character of the installation, and which with satisfactory bacterial results would be ample return for the investment at the present time. Improvements in results did not, however, cease with 1910. While the additional investment by the company since that date has been very small, not only has there been a constantly higher quality of effluent produced, as will be shown, but the production per acre of sand surface has increased to 6 million gallons (Table III). This would have required, in addition to the 4.656 acres now in use, an addition of 2.328 acres at a cost of not less than $186,000. ($20,000 per million gallons daily capacity.)

SAND HANDLING AND CLEANING METHODS.

The methods in use in handling sand have materially aided the increased production of water. When the plant was first put in service material was placed in the filters by hand, using wheelbarrows, and the soiled material was removed in the same fashion. The first improvement in sand handling methods was the adoption of the sand ejector for removing material from the filter, but it was still replaced by wheeling in. Next the wheeling-in method was discarded and the material was washed back into the filter from the ejector into a double box arrangement from which the sand, first drained of its carrying water, was thrown by hand into place in the filter. There was, about 1908, in use in Washington what is known as the washing-in method of sand restoration, that is, carrying above the filter surface a head of water approximately the depth to which it was desired to restore sand, returning the sand to the filter with the ejector and allowing it to flow from an open end of the hose suspended at the end of the boat, into the water where it fell to the sand surface and piled up to the height desired. While this method was used for several years at the Indianapolis plant, it was discarded because of the fact that it did not seem possible to avoid the formation of a silt layer at the point where the old and new sand layers joined and at the same time bring about a very decided stratifica-

TABLE II

WATER AS PRODUCED FROM THE FILTERS. MONTHLY AVERAGE TOTAL RATE PER DAY

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1908	3.37	3.32	3.79	8.	11.35	14.18	14.86	13.88	11.24	10.75	9.84	11.9	9.82
1909	14.3	14.4	13.6	13.1	14.6	15.7	16.	17.1	15.3	16.8	14.2	18.	15.4
1910	14.	16.7	15.7	16.3	17.2	18.7	19.6	19.4	18.5	16.7	16.1	18.7	17.3
1911	16.9	18.5	18.1	17.2	20.1	21.5	22.2	21.7	20.9	19.1	19.	17.2	19.35
1912	21.1	20.7	17.6	18.1	19.8	21.3	20.4	20.6	20.2	17.9	15.8	19.3	19.35
1913	16.9	18.5	16.2	17.4	20.8	23.7	21.1	21.5	21.5	21.1	20.9	20.7	20.03
1914	20.4	22.8	19.3	15.4	17.8	22.5	26.	22.5	20.2	21.2	20.5	16.	20.928
1915	20.7	17.3	18.	15.2	17.7	16.5	15.	17.1	19.9	19.6	18.3	18.7	18.203
1916	14.	14.1	18.2	16.	19.2	18.75	23.9	21.7	22.6	22.3	22.1	22.5	19.943
1917	20.5	20.5	15.6	16.5	19.2	19.4	20.9	23.2	21.4	21.3	22.4	24.1	20.716
1918	25.6	19.7	20.2	19.9	23.6	26.3	24.1	21.5	20.2	22.4	22.4	20.6	22.186
1919	23.	23.6	20.7	22.9	22.8	23.5	26.4	24.2	25.9	24.5	22.1	26.4	23.82
Avg. 12 yrs.	19.3	19.2	18.	17.5	19.8	21.2	22.0	21.3	21.1	20.6	20	20.4	20.183

TABLE II-A

GENERAL SUMMARY FILTERED WATER PRODUCED 1904-1920

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1904	....	....	....	....	....	....	....	....	20.25	60.5	111.3	224.2	416.250
1905	88.75	87.55	73.25	123.09	191.57	228.18	233.35	220.360	192.310	218.64	192.99	243.120	2,093.16
1906	269.94	274.26	357.74	264.4	287.72	265.82	357.19	380.37	403.36	407.3	416.85	425.96	4,131.91
1907	326.76	385.	351.18	378.29	277.5	223.52	314.83	336.4	329.67	334.54	324.761	292.964	3,875.415
1908	113.631	96.397	117.455	240.023	354.446	429.302	459.707	427.851	335.211	333.597	296.39	378.904	3,582.914
1909	459.705	417.565	432.635	404.849	451.803	469.634	497.379	530.660	465.814	522.203	424.752	559.174	5,636.172
1910	434.7	461.525	485.204	489.587	533.702	560.127	607.065	600.493	554.114	516.865	483.537	580.650	6,307.569
1911	525.185	517.237	560.220	516.513	622.001	643.684	687.609	670.813	625.780	590.495	570.187	532.302	7,062.036
1912	655.198	579.983	544.385	543.321	613.902	640.109	632.423	638.795	607.138	555.839	473.462	598.764	7,083.319
1913	523.607	517.437	501.024	522.03	645.26	712.633	654.369	665.904	645.448	653.547	627.137	642.943	7,311.339
1914	632.733	637.353	598.308	561.338	651.943	673.621	806.514	698.903	607.917	657.731	616.425	496.000	7,638.786
1915	646.233	485.98	557.511	557.409	547.118	495.904	487.032	529.314	598.247	608.346	550.396	580.894	6,644.384
1916	433.179	403.794	579.284	580.947	596.087	562.630	741.395	671.2	679.347	692.155	663.294	695.845	7,299.157
1917	643.590	575.488	483.925	592.076	594.895	581.686	646.461	719.427	642.322	661.363	673.318	745.664	7,560.215
1918	792.348	551.531	626.716	596.520	731.412	789.275	748.245	667.875	609.481	696.552	678.846	643.023	8,131.824
1919	714.516	663.873	642.918	687.055	708.196	705.402	820.867	751.773	778.406	762.321	665.678	818.706	8,719.711
1920	941.409	618.750	663.061	721.937	792.758	793.775	652.787	785.018	815.282	794.325	675.793	787.360	9,042.255

TABLE III

DAILY RUNNING RATE PER ACRE OF SAND SURFACE. AVERAGES BY MONTHS

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1908	.75	1.18	1.86	2.35	2.54	3.14	3.4	2.97	2.7	2.48	2.43	2.98	2.54
1909	3.76	3.23	3.35	3.45	3.79	3.62	3.87	4.11	3.8	3.9	3.57	4.23	3.74
1910	3.6	3.83	3.58	3.75	3.8	4.44	4.44	4.54	4.24	4.29	3.85	4.41	4.06
1911	4.71	4.14	4.04	4.15	4.61	4.96	5.	5.	4.84	5.	4.42	4.01	4.57
1912	4.96	4.9	4.35	4.87	4.81	4.83	4.66	4.67	5.09	4.33	3.54	4.4	4.62
1913	3.97	4.12	4.22	4.3	5.15	5.59	4.83	5.07	5.38	5.38	5.22	4.73	4.885
1914	4.56	5.2	4.46	3.69	4.41	5.32	6.	5.37	5.04	5.59	5.3	3.68	4.95
1915	5.1	4.03	4.1	3.5	4.4	4.32	3.39	3.77	4.57	4.93	4.25	4.43	4.28
1916	3.62	3.65	4.92	4.13	5.11	5.	5.35	5.4	5.6	5.18	5.04	5.08	4.94
1917	4.91	5.33	4.07	5.33	5.13	4.77	5.43	5.63	5.34	5.71	5.2	5.75	5.19
1918	6.45	5.77	5.43	5.86	6.16	6.19	5.76	5.51	5.17	5.73	5.32	4.57	5.61
1919	5.77	5.55	5.11	6.08	5.80	5.49	6.24	6.21	6.26	6.42	5.53	6.65	5.94
Avg. 12 yrs.	4.76	4.65	4.43	4.57	4.94	5.09	5.11	5.12	5.15	5.26	4.77	4.77	4.9

TABLE IV

PER CENT. OF TIME THAT FILTER WAS OUT OF SERVICE FOR CLEANING, ETC., BY MONTHS

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1904	....	....	....	....	....	....	....	....	1.8	.6	10.3	7.5	
1905	29.1	35.7	36.1	18.9	25.9	36.8	40.2	35.2	35.4	38.6	30.7	3.2	....
1906	7.3	6.1	4.7	13.5	40.9	40.4	26.3	9.5	6.2	9.	8.8	5.9	....
1907	7.2	8.	12.3	14.1	16.4	11.3	6.2	15.2	6.9	6.3	8.9	13.	....
1908	3.6	39.3	55.9	27.5	4.7	7.6	6.8	8.1	9.8	7.7	13.8	14.7	....
1909	18.6	9.1	13.8	16.7	17.	6.9	5.5	10.8	13.2	7.5	8.8	9.3	16.63
1910	7.3	7.8	6.1	6.4	5.6	9.8	5.8	8.	7.3	6.1	9.1	15.6	11.4
1911	17.7	4.	4	10.9	6.7	7.	6.7	6.5	5.5	18.1	7.7	10.	7.9
1912	8.7	9.2	13.2	20.1	11.5	5.2	5.8	5.2	14.8	11.	4.	5.7	8.7
1913	6.5	1.3	16.6	10.1	11.3	8.2	4.2	6.9	12.3	13.9	12.1	3.9	9.5
1914	4.8	5.7	7.2	10.4	15.7	8.9	6.9	9.9	13.9	9.4	7.4	6.5	9.
1915	3.4	7.8	5.5	6.9	17.5	17.8	5.1	2.4	7.1	14.6	7.5	9.2	8.9
1916	16.9	17.	20.4	17.1	19.4	19.2	4.2	13.6	13.5	7.5	5.9	4.9	8.8
1917	10.3	17.4	17.7	14.8	19.7	12.7	17.3	11.5	13.9	20.	7.3	10.2	13.3
1918	14.9	26.7	20.	27.2	17.7	8.7	10.	16.1	15.9	16.3	9.5	3.1	14.4
1919	14.8	8.5	13.	18.2	17.4	8.3	9.2	16.6	11.1	18.3	14.2	14.8	15.4
													13.8
Avg. 15 yrs.	10.5	10.5	12.40	14.2	14.2	10.6	7.5	9.7	11.5	13.5	8.5	8.4	11.

Lost time is the number of possible running hours that the plant is out of service for cleaning, etc. The possible hours are: 28-day month, 4032; 29-day month, 4,176; 30-day month, 4,320; 31-day month, 4,464.

Figures for 1904-5 based on three filter units of 1.6 acres each, 4.8 acres total. No lost time is figured until unit makes its first run, nor is account made of time lost during reconstruction.

Following reconstructiion, all rate figures are based on 6 units of .776 acre each. 4.656 acres total.

tion of the sand dependent upon the relative specific gravity of the various grain components of the total sand layer.

In 1914 a modification of the Nichols washing-in place method was adopted and still is used.

The changes in sand handling cost may be summarized briefly as follows: The original method with labor costing from 12½ to 15 cents an hour involved the expenditure of $1.25 per yard of material handled for removal, washing and replacing. The use of the stilling box instead of the wheeling-in reduced the cost to $1.00 per yard. Various improvements in the sand handling capacity of ejectors used and the washing-in method of restoring reduced the cost until in 1911 and 1912 the total expenditure was 40.5 cents per cubic yard for scraping, ejecting, washing, replacing and smoothing sand. Adoption of the washing-in place method eliminated an additional handling of sand outside the filter unit and with labor at 22½ cents an hour made the total cost of sand handling 25 cents a cubic yard in 1917. In 1919, with labor at 40 cents instead of 22½, and decreased efficiency of the laborers, the cost increased to 55 cents, which is, however, as will be remembered, lower than the conditions under which the plant operated originally.

Remembering the fundamental proposition that sand handling is the key to the successful operation of the slow sand filtration plant, it becomes increasingly a matter of displeasure to the writer to confess the relatively small mechanical improvements which have been made in this operation. It will be remembered that the Pittsburgh plant installed equipment built by the Blaisdell Manufacturing Co. for removing and restoring sand. Likewise Wilmington, Del., constructed its filtration plant in such a way as to accommodate the Blaisdell washing-in place machine. Later developments under the direction of Nichols at Philadelphia have resulted in certain improvements in the method of removing soiled sand from the filter. It still remains necessary, however, under the present condition of labor shortage and inefficiency to attempt to increase in every way possible the mechanical methods of handling sand, and the chief thing to be desired in the operation of a slow sand plant is a piece of equipment—relatively light and easily movable—which will remove soiled sand, wash it and replace it in the sand layer.

PRELIMINARY COAGULATION.

The application of the coagulant is not necessary at all times. The preliminary coagulation of White River water begins ordinarily when the turbidity is between 30 and 40 parts per million. The range of turbidity of the raw water throughout the life of the plant is such that 56.1% of the time the turbidity is less than 30. During the summer months, however, coagulant is used to assist in algae reduction. The false information obtained by averages is no more clearly shown than in an analysis of the range of raw water turbidity at any filtration plant. (See Tables V and VI.) For example, White River water at Indianapolis averages throughout all the years under record 40 parts per million turbidity. Analyzing these figures more closely, during only 18.6% of the time does the turbidity exceed 50 parts per million, while on the other hand during 39.5% of the time the turbidity is less than 20. On only 2.7% of the days during the entire life of the plant has the turbidity exceeded 200 parts per million, yet the operating data referred to previously indicates beyond question the cumulative effect of handling without preliminary treatment the excess turbidity in so small a percentage of the total number of days. The days of the year during which coagulant was applied to the raw water have varied from 149 to 225, and the average pounds per million of coagulant used ranged from 118 to 275. (See Table VII.)

It was the opinion when pre-treatment was first decided upon that lime and iron treatment would be applicable to the local situation. This opinion was furthered by the conspicuous success of two plants nearby which operated with a raw water having high turbidity. Experience showed that White River water on very few days in the year carries such character and quantity of suspended material as to make this method satisfactory, and on a great many days of the year, a relatively slightly turbid water (and this turbidity largely colloidal) is not satisfactorily treated except with Sulfate of Alumina. Tables V and VI detail the turbidity of the raw and settled water and Table VII the summary as to use of coagulant.

TABLE V-A

1904–1919, RAW WATER RANGE OF TURBIDITY (Parts per Million)

Year	0–10	11–20	21–30	31–40	41–50	51–100	101–150	151–200	Over 200	Test Days	Max.	Min.	Avg.
1904	10	67	16	0	0	2	2	4	0	101	200	5	19
1905	94	118	65	20	10	36	9	7	6	365	300	3	24
1906	183	91	30	25	9	19	3	4	1	365	200	5	17
1907	8	91	70	54	73	49	8	4	8	365	400	6	40
1908	90	44	51	79	34	41	8	8	11	366	300	5	44
1909	27	32	58	65	60	67	24	7	25	365	1029	5	67
1910	31	80	105	51	34	48	10	5	1	365	229	5	32
1911	49	67	60	86	45	44	6	5	3	365	306	3	35
1912	37	64	37	73	60	41	16	15	23	366	665	3	61
1913	20	92	46	71	46	61	11	6	10	363	892	5	46
1914	112	75	83	61	14	15	3	1	1	365	220	3	25
1915	142	48	48	42	21	38	14	4	7	364	712	3	35
1916	104	43	47	80	33	33	11	2	12	365	388	3	39
1917	69	51	64	73	15	40	28	4	19	363	610	3	66
1918	61	53	80	46	40	44	9	13	14	360	317	3	47
1919	117	28	66	72	20	40	8	9	9	359	647	2	42
Total.	1154	1044	926	898	514	618	170	98	150	5562	1029	2	40
% time.	20.7	18.8	16.6	16.1	9.2	11.1	3.0	1.8	2.7	100			

TABLE V-B
1908–1919, SETTLED WATER RANGE OF TURBIDITY (Parts per Million)

Year	0–10	11–20	21–30	31–40	41–50	51–100	101–150	151–200	Over 200	Test Days	Max.	Min.	Avg.
1908	107	33	3	1						144	32	3	9
1909	140	188	21	8	3					360	65	4	15
1910	82	202	33	2						319	35	3	15
1911	250	95	6	2						353	40	3	10
1912	43	245	48	3	0					339	30	3	13
1913	378	162	1							341	25	3	9
1914	329	19	0							348	20	2	7
1915	345	2	0							347	20	3	5
1916	352	5	0							357	15	2	5
1917	307	28	4							339	30	2	7
1918	318	32	2							352	25	2	8
1919	353	6								359	15	2	6
Total.	2804	1017	118	16	3					3958	65	2	9
% time.	70.9	25.7	2.9	.4	.1					100			

TABLE VI-a
1912–1919 RAW WATER RANGE OF COLOR

	1912	1913	1914	1915	1916	1917	1918	1919	Total
0–10	27	56			1		22	50	156
11–20	227	233	284	79	3	15	160	199	1200
21–30	60	59	56	127	85	31	97	72	587
31–40	26	8	20	81	121	124	36	20	436
41–50	13		4	44	59	61	15	8	204
51–100				30	69	100	26	4	229
101–150				4	13	10	4	3	34
151–200					4			3	7
Over 200					9	3			12
Maximum	50	40	50	140	480	600	140	200	600
Minimum	8	5	12	15	10	15	5	5	5
Average	20	17	20	35	53	53	28	23	31
No. Samples	353	356	364	365	364	344	360	359	2865

TABLE VI-b

1912-1919 SETTLED WATER RANGE OF COLOR

	1912	1913	1914	1915	1916	1917	1918	1919	Total
0-10	160	144	5	....	1	10	134	229	683
11-20	161	196	330	232	102	33	190	128	1372
21-30	13	2	12	82	129	168	22	2	430
31-40	....	....	1	24	71	51	2	....	149
41-50	....	....	....	4	28	53	2	....	87
51-100	....	....	....	5	24	20	2	....	51
101-150	....	....	....	....	....	....	....	....	....
151-200	....	....	....	....	....	....	....	....	....
Over 200	....	....	....	....	....	....	....	....	....
Maximum	30	28	35	70	95	90	70	25	95
Minimum	5	5	8	12	10	5	3	5	3
Average	13	12	16	24	30	32	15	11	19
No. Samples	334	342	348	347	355	335	352	359	2772

TABLE VI-c

1912-1919 FILTER EFFLUENT RANGE OF COLOR

	1912	1913	1914	1915	1916	1917	1918	1919	Total
0-10	302	316	253	220	197	117	336	359	2100
11-20	55	41	109	142	151	234	23	....	755
21-30	3	....	....	3	13	6	2	....	27
31-40	....	....	....	....	1	2	....	....	3
41-50	....	....	....	....	....	....	....	....	....
51-100	....	....	....	....	....	....	....	....	....
101-150	....	....	....	....	....	....	....	....	....
151-200	....	....	....	....	....	....	....	....	....
Over 200	....	....	....	....	....	....	....	....	....
Maximum	30	18	17	25	35	35	30	10	35
Minimum	5	3	5	10	5	5	3	5	3
Average	9	8	11	12	12	14	7	6	10
No. Samples	360	357	362	365	362	359	361	359	2885

TABLE VII

COAGULATION SUMMARY

Year	Days Coagulant Used	Million Gallons Treated		Turbidity		Pounds Coagulant Used			Pounds per Million Gallons		
		Lime-Iron	Alum	Using Iron	Using Alum	Iron	Lime	Alum	Iron	Lime	Alum
1908	82	....	1,312.900	....	....	....	....	208,895	....	....	159
1909	197	1,487.100	1,794.400	150	63	369,037	383,766	214,723	248	258	120
1910	158	328.400	2,720.800	125	52	105,508	111,940	322,401	321	342	118
1911	204	278.800	4,361.200	95	50	66,191	101,283	590,239	238	363	135
1912	183	13.700	3,394.300	....	107	5,700	8,760	933,651	83	64	275
1913	225	....	4,467.900	....	65	....	....	805,230	....	....	180
1914	149	....	3,211.200	....	43	....	....	418,600	....	....	133
1915	149	....	2,427.500	....	63	....	....	495,783	....	....	204
1916	193	44.300	3,485.200	126	60	11,350	9,470	530,250	256	213	152
1917	225	96.900	4,281.000	158	101	27,240	30,620	683,369	281	316	160
1918	232	154.200	4,651.600	66	63	53,500	31,680	696,350	347	205	150
1919	222	....	5,203.500	....	63	....	....	672,250	....	....	130

In very condensed form the range of raw water turbidity and rate of coagulant required may be expressed as follows:

RAW WATER TURBIDITY.

Range	Total Test Days 1904-1919	% of Time	Pounds per m. g. Alum Used
0- 10	1154	20.7	...
11- 20	1044	18.8	...
21- 30	926	16.6	...
31- 40	898	16.1	65
41- 50	514	9.2	95
51-100	618	11.1	180
101-150	170	3.0	285
151-200	98	1.8	370
Over 200	150	2.7	450

By the inclusion of this table in this place it is not meant to indicate that these amounts are not necessarily varied from time to time. The temperature of the raw water, together with the fineness of the suspended matter therein contained and the proportion of living vegetable material all produce different effects upon coagulant which make its use one not capable of being carried out by following the same set table but depending altogether upon the intelligent and constant observation of the effect of actual use of coagulant upon the particular water being treated at the time.

CHLORINATION.

The experimental studies on the use of hypochlorite of lime at Boonton, N. J., and the Bubbly Creek Plant at Chicago were investigated by this company, and beginning in July of 1909, hypochlorite of lime was applied to the Indianapolis water supply. The use of hypochlorite of lime continued until May of 1916 when the Wallace-Tiernan dry feed chlorinator was put in service and in January of 1920 the dry feed chlorinators were modified to apply the chlorine in solution form. During the first three years of the use of the hypochlorite of lime an average of 3 pounds per million gallons was used, expressed as chlorine. This was later reduced to an average of 1¾ pounds per million gallons and the same amount was used when the shift was made to the use of chlorine gas. The average quantity has increased during the last two years to approximately 2 pounds per million gallons due to a more stringent requirement within the organization as to the quality of the final effluent. Table VIII summarizes the use of chlorine products.

TABLE VIII

CHLORINATION SUMMARY

Date	Million Gallons Treated	Total Pounds Hypo-Chlorite Used	Per Cent. Available Chlorine	Pounds Chlorine or Equivalent Used	Pounds Chlorine per Million Gallons
1909	....	....	....	....	3.4
1910	....	....	....	....	3.4
1911	6,528.772	51,853	33.1	17,170	2.64
1912	6,700.000	50,250	33.3	16,750	2.5
1913	7,044.600	33,000	34.4	11,352	1.61
1914	7,306.959	38,880	34.7	13,481	1.85
1915	6,148.793	37,861	34.3	12,986	2.11
1916	2,145.769	9,945	35.2	3,501	1.64*
1916	5,134.191	....	....	8,619	1.68**
1916	7,279.960	....	....	12,120	1.67***
1917	7,489.287	....	....	14,548	1.94
1918	8,082.482	....	....	15,519	1.9
1919	8,718.511	....	....	15,228	1.75

*Hypo to May. **Chlorine from May. ***Total for year.

COPPER TREATMENT.

During the summer months the growth of micro-organisms in the raw water, if not specially treated, would produce offensive conditions in the settling basin and taste in the filtered water. The well known copper sulfate treatment has become a part of the summer routine and Table IX shows the amount and period during each year that it is used. It is recognized that copper sulfate is no more than a sedative and that algae growth cannot be stopped in open reservoirs without complete removal of the half-bound carbonic acid upon which the organisms thrive. The theory upon which the treatment is carried on is simply that of holding at a low figure the micro-organic growth until the water reaches the covered filters and reservoirs, when the absence of sunlight reduces the difficulty to a minimum.

TABLE IX

GENERAL SUMMARY USE OF COPPER SULFATE

Date	Mil. Gals. Treated	Pounds Used	Lbs. per Mil. Gal.	Number of days during months of—
1911	903.071	3,763	4.14	42—May, June, July, August.
1912	95.263	494	5.18	5—May.
1913	1,285.948	3,010	2.34	60—April, May, June, July, August.
1914	570.560	1,443	2.78	26—May, June.
1915	998.210	1,480	1.49	50—August, September, October.
1916	986.730	871	.9	45—August, September, October, November.
1917	1,588.300	2,046	1.29	67—July, August, September.
1918	2,455.7	4,832	1.97	104—June, July, August, September.
1919	2,268.20	4,837	2.14	91—June, July, August, September.

BACTERIOLOGICAL EXAMINATIONS SUMMARIZED.

The Indianapolis Water Company established one of the very first privately owned laboratories in connection with a water system in November, 1903, and the investigations of the quality of the supply as well as various technical details of laboratory work have been carried on continuously since that date. From 10 to 15 thousand samples of water are handled annually. It is not possible to go into a complete discussion of details of the bacteriological content of the supply. (Refer to close of paper for complete tables of bacteriological findings.) The number of organisms growing at 37° C. in the plant effluent and the B. Coli content are sufficiently indicative of the condition of the water. Daily examinations of the plant effluent with incubation at 20° were carried on from the beginning of the operation of the laboratory. 37° counts were not made continuously until the year 1912. From that date until the present time an analysis of the figures indicates that 43.5% of the time the 37° count is less than 5 per cubic centimeter; 33.5% of the time from 6 to 10; 17.3% of the time from 11 to 20; 2.9% of the time from 21 to 30; 3.8% of the time from 30 to 100; with one day since the beginning of the 37° counts a bacteriological content of the filter plant effluent in excess of 100 per cubic centimeter. The average has ranged from 5 per c. c. in 1916 to 12 in 1912. Studying the quality of the finished water as referred to the presence of the Bacillus Coli, during 74.5% of the time no B. Coli are found in 100 c. c. of the effluent, 17.9% of the time 1 or 2 B. Coli per 100 c. c. are present, 3.5% of the time 3, 4 or 5 per 100 c. c., 3.3% of the time from 6 to 10 inclusive, and 0.52% of the time more than 10. The average B. Coli content per 100 c. c. of the filter plant effluent is 0.85.

QUALITY OF RAW WATER.

In the studies of the total number of organisms growing at 37° C. in the water in the various stages of the purification process in combination with the studies as to B. Coli content, there are certain striking characteristics of the figures from season to season and year to year which are worthy of comment. The first refers to the condition of the White River water reaching the local plant. It will be remembered that in

1914 certain standards of water purification and sewage treatment were laid down by engineers at the request of the International Joint Commission, in its investigation of the pollution of the Great Lakes. In paragraph 4 the statement was made, "While present information does not permit a definite limit of safe loading of a water purification plant to be established, it is our judgment that this limit is exceeded if the annual average number of B. Coli in the water delivered to the plant is higher than about 500 per 100 c. c." This statement has a great many possibilities of interpretation, not alone in the language used but with reference to the viewpoint from which this Board of Engineers was looking at the broad question. They were not alone considering the operation of purification plants but the degree of efficiency to which sewage purification plants should operate in discharging their effluent into streams which later might be used for water supply. It is the impression of the writer that they, as well as a great many other persons at the same time, had not had access to a large volume of figures referring to the actual conditions which water purification plants had to meet. It will be remembered that in previous discussions in this Association with reference to the standards for water used on interstate carriers, regret has been expressed at the real lack of a mass of information as to the quality of filtered water in municipalities where no question is raised as to quality, and even at the present time the lack in uniformity in expression of results and in volume of work done is so great as to make real comparisons difficult. In a great many well operated plants (using the term well operated with reference to the mechanical conditions and the actual quality of the finished product) the volume of laboratory studies is not sufficient to be used as a basis of broad conclusions. Studies on the B. Coli content of White River have been summarized in such a way as to cover the operations during the last five years (see page 25) and during that period the ranges in the number of B. Coli per 100 c. c. have varied from 695 as a minimum in September, to 9,076 in March. In other words, the minimum B. Coli content of White River at Indianapolis is higher than the expressed safe limit of the International Joint Commission. This is not an abnormal figure for streams in the northern part of the United States. On the other hand, it appears very probable

from such studies as can be referred to on the waters purified in the part of the country east of St. Louis and north of Washington, that the B. Coli content averages as high or higher than this amount.

One of the principal objects in adding such a mass of material to this discussion has been to show as thoroughly as possible what results can be attained in a carefully controlled filtration system.

Limitations such as have been set by the Joint Commission are undoubtedly proper, if in their promulgation, sufficient consultation has been made with actual results attained, and a check placed upon theoretical considerations.

The operation of purification plants in this country has been attended with striking reductions in typhoid death rates. The results for Indianapolis are attached to this paper. If the reduction in this type of illness is to be attributed to improvement in water supply, as has been done, then it must follow correlatively that the load these plants have had to bear is not too heavy for their successful operation. Engineers cannot point to the success in reducing water-borne diseases as an argument for building filter plants, and at the same time, set as the limit for their successful operation, a figure, which if literally enforced, would legislate from use the water which these plants are purifying.

This, incidentally, is not said for the purpose of condoning carelessness in the treatment of municipal sewage. Observations make clear the fact that municipal sewage is being discharged without purification to such an extent as to sensibly increase the organic loading of many streams. Without respect to the results that can be attained in purifying such water, it is not equitable that the plain duty of sewage purification should be neglected with the result of increasing the load that water purification plants have to bear.

SEASONAL VARIATIONS OF BACTERIAL FLORA DURING FILTRATION PROCESS.

Certain variations in bacterial flora have been observed from season to season which may partly be local in their significance, but others of which may not only apply to surface waters of the Central States but to all such supplies in temperate climates.

The findings as to 20° bacterial growth and 37° bacterial growth and numbers of organisms of the colon group have been studied in detail over a period of 5 years. This data is summarized in tabular form under the following headings:

1. Basic tables. Bacteria at 20° C.—37° C. and Colon Group.
2. Percentage which 37° Count is of 20° Count.
   Percentage of 37° organisms which are of Colon Group.
   Percentage of Colon Group which are fecal type.
3. Effect of various steps of Purification process on different types of bacteria.

The fundamental seasonal variation as evidenced by the enumeration of the total number of bacteria present, as well as those of the specific colon group, is that of greater concentration of bacterial life during the months of low temperatures and low concentration during high temperature months, or briefly, a variation inversely proportional to the temperature. This may be accounted for by the greater proportion of destruction of micro-organisms during the season of the year when biological activity is at its highest. The bacteria derived from the sewage pollution and field washings entering the streams during the warm temperature months are subject to the destructive activities of other forms of bacterial and plant life, whereas these agencies being absent or inactive during the winter months tends to prolong the existence of bacteria derived from external polluting sources.

Following the water through the various steps of the filtration process there is a lessening of the seasonal variation, the filtered water showing a less variation between the bacterial concentration of the summer and winter months than is the case with the raw water. A slight reversal of this condition occurs in the sterilized effluent, where the variations again become somewhat greater.

A comparison of the total number of bacteria as evidenced by counts made after incubation at 20° C. and 37° C., expressed in the percentage which the 37° count is of the 20° count, shows that the blood temperature organisms form their lowest proportion of the total bacterial flora during the cold winter months, the minimum being 25% during February. They reach their maximum proportion of the 20° organisms

BASIC TABLES

Bacteria per c. c. 20° C.—5 years.
Bacteria per c. c. 37° C.—5 years.
B. Coli per 100° C.—5 years, 1915-1919.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Raw Water—20° per c. c.	4,632	10,743	7,020	1,555	1,297	1,354	585	406	422	1,272	1,014	2,293
37° per c. c.	1,433	2,732	2,293	736	966	1,063	453	356	462	616	625	1,017
Colon per 100 c. c.	6,637	5,650	9,076	3,458	3,727	1,447	1,036	870	695	917	5,566	2,601
Settled Water—20°	2,546	3,594	1,702	381	292	148	147	209	122	179	508	1,544
37°	627	428	224	131	193	137	152	360	180	125	244	460
Colon	2,150	1,071	631	182	282	108	156	69	44	51	962	963
Filtered Water—20°	420	357	90	29	30	45	85	38	29	24	78	264
37°	88	50	49	10	16	41	64	48	53	18	19	41
Colon	389	103	27	4.6	4.5	5.7	8	3.6	4.9	5	27.3	104
Sterilized Water—20°	47	87	5	4	5	6	7	6	5	7	7	71
37°	16	15	10	5	5	5	5	6	5	6	6	13
Colon	2	.74	.49	.39	.56	.37	.3	.47	.32	.7	.49	2.1

Comparison of Total Counts at 20° C and 37° C.
Expressed in per cent. which 37° count is of the 20° count—5 years, 1915-1919

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Raw Water	31	25	33	47	74	77	78	88	110	48	55	44
Settled Water	25	12	13	35	66	93	103	172	147	70	48	30
Filtered Water	21	14	21	35	53	91	75	126	183	75	24	15
Sterilized Water	34	17	200	125	100	83	71	100	100	85	85	18

Percentage of 37° organisms which are bacteria of the Colon Group—(5 years).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Raw	4.6	2.1	4.	4.7	3.9	1.4	2.3	2.4	1.5	1.5	8.9	2.6	3.1
Settled	3.4	2.5	2.8	1.4	1.5	.8	1.	.2	.2	.4	4.	2.	1.5
Filtered	4.4	2.	1.4	.4	.3	.1	.1	.07	.1	.3	1.4	2.5	1.6
Sterilized	.12	.05	.05	.08	.11	.07	.06	.08	.06	.12	.08	.17	.10

Percentage of organisms of the Colon Group which are fecal type (positive reaction to Methyl Red)—3 years.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Raw	55	71	73	74	79	62	61	46	73	71	64	71	66
Settled	63	63	61	66	78	65	48	23	72	66	58	65	61
Filtered	66	80	71	65	70	46	32	23	47	57	58	67	58
Sterilized	70	60	34	31	13	42	25	18	50	57	55	81	56

Effect of Various Steps of Purification Process on Bacterial Growth—1915-1919
Evidenced by Reduction of 20° Growers, 37° Growers and Colon Group

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Reduction by settling and partial coagulation:	20°	45	67	76	76	78	89	75	49	71	86	55	33
	37°	66	84	90	82	80	87	70	-1	61	80	61	60
	Colon	68	81	93	95	93	93	85	92	94	94	83	63
Reduction by filtration of settled water:	20°	83.5	90	94.7	93.4	90	70	43	82	76	87	85	83
	37°	86	88	92	92	92	70	58	87	71	84	92	91
	Colon	82	91	96	97.5	98.2	94.8	95	95	89	90	97	89
Reduction by sterilization of filtered water:	20°	89	75	94.5	86	84	87	91.8	84	83	71	91	73
	37°	82	70	47	50	69	88	92	87.5	91	67	69	68
	Colon	99.5	99.3	98.2	99.2	98.8	99.4	99.6	98.7	99.4	98.6	98.2	98.1
Reduction by entire process:	20°	99	99.2	99.93	99.75	99.62	99.56	98.8	98.5	98.8	99.45	99.4	96.9
	37°	98.9	99.5	99.5	99.3	99.5	99.5	98.9	98.3	98.9	99.	99.	98.9
	Colon	99.97	99.99	99.99	99.99	99.98	99.98	99.97	99.95	99.96	99.93	99.99	99.92

during the month of August, 88%. The same variation or ratio between 20° and 37° organisms holds true in water after settling, filtration and sterilization, except that as each step improves the sanitary quality of the water the 37° proportion is lowered during the cold months and equals or becomes greater than the 20° count during the summer months. Studying the 37° organisms and the proportion of these which are organisms of the colon type, it is noted that the percentage of B. Coli is highest during the cold weather months with an average of 3.1% of the 37° organisms conforming to the test for the colon group, the maximum in any month is 8.9% in November and 1.4% minimum in June. The coagulation and settling process alone reduces the average percentage of organisms of the colon type from 3.1% to 1.5% with variations from a minimum of .2% in the month of August to 4% in November. In the filtered water, with a seasonal average of 1.6% of the 37° organisms B. Coli, the variation is from a minimum of .07% in August to 4.4% in January. The sterilization process produces a remarkable reduction of the organisms of the colon type as expressed in this percentage ratio. With an average of .1% of the 37° organisms B. Coli throughout the year, the maximum is .17% in December and the minimum .05 for February and March and .06 in July and September. The minimum of .05 for February and March indicates either a failure of conformance to any seasonal variation on the part of the efficiency of chlorine or an elimination due to the use of a large amount of coagulant during these months. The latter is more probably the reason. The reduction of organisms of the colon group by the sterilization process is so great as to indicate a practical selective action against this type of bacteria.

Another series of examinations of the filtered and sterilized water has shown that approximately 25% of the filtered water organisms are spore formers, whereas 75% of the sterilized water organisms are spore formers. Taking this in combination with the number of B. Coli present, the selective action due to sterilization may be shown in the following manner: Of 1,000 organisms in the filtered water 250 will be spore formers and 16 organisms of the colon type. Of 1,000 organisms in the sterilized water 750 will be spore formers and one will be of the colon type. Of the nonspore forming or-

ganisms then in the filter effluent 2.16% are Coli type, while in the sterilized water only .4% are such, a 5 to 1 reduction.

A study has been made over a period of three years of the organisms of the Colon Aerogenes Group which are of the fecal type, that is, having a positive reaction to Methyl Red. In the raw water there seems to be no seasonal variation, the minimum being 46% in August and the maximum 79% in May, that is, 46% of the total number of completed B. Coli were of the fecal type. The steps in the filtration process, however, develop an elimination which by the time that the sterilization process has been completed has a decidedly seasonal variation, the Methyl Red positive organisms reaching their minimum percentage during the warm months and their maximum in the cold months. In other words, the survival of fecal B. Coli is less likely during the season of the year when biological activity is at its highest.

Studying the reduction by the various steps in the purification process it will be noted that the reduction by settling and partial coagulation is lowest during the winter months and highest in summer. The same is true of the filtration step except that the variations from season to season are less. The irregularity of percentage reduction by sterilization process would indicate that there is no seasonal factor in the efficiency of chlorination. Studying the percentage reduction by the entire filtration process, it is beyond question the fact that organisms of the colon type are less likely to survive filtration and sterilization than is either the low temperature group as evidenced by the 20° or the blood temperature group as evidenced by the 37° count.

CONCLUSION.

1. Bacterial concentration in streams and partially purified water is inversely proportional to the temperature.

2. The proportion of all organisms, which are of the general colon type, is likewise inversely proportional to the temperature.

3. Both settling and filtration exercise a selective action against organisms of the Colon type, and sterilization with chlorine products exercises a remarkably increased selective action against these organisms.

4. Of the total number of Coli type organisms present, the

Methyl Red positive or so-called fecal type survive the purification processes, step by step, in increasingly less proportion as the temperature rises.

REDUCTION OF TYPHOID FEVER RATE.

The installation of water purification plants assists in reducing materially both general and typhoid death rates. As a matter of fact, the Mills-Reincke phenomenon, so-called, indicates that elimination of intestinal disorders results in material reduction in various other seemingly dissociated death rates.

As a corollary to the laboratory data presented in this discussion, it is worth while to note the data as to general and typhoid death rates in Indianapolis since 1891.

Previous to the installation of the filtration plant, the typhoid death rate was high, reaching epidemic amounts in 1893, 1895 and 1904. The average for all years was 51.8.

After the plant was placed in operation, the reduction in rates proceeded slowly, but finally to a very satisfactory rate in 1918 and 1919. In 1916 there was a decided rise in typhoid deaths, summer typhoid associated with swimming in polluted streams. The general average typhoid rate since 1905 has been 22, a reduction to 43% of the pre-filtration days.

In 1904, when there was an investigation of the water supply and general sanitary conditions in Indianapolis, in addition to recognizing the necessity of completing the filtration plant already under construction, it was recommended that the large number of private wells and unsanitary privies be eliminated. Repeatedly since that time various individuals have urged that the same action be taken, but no result has obtained.

Studies of typhoid cases over a period of years locates over 80% of the total as occurring where a private well or privy or both are used. If Indianapolis performed its duty in improving sanitary conditions as well as the Indianapolis Water Company has fulfilled its duty to the public the typhoid death rate would be less than 1 per 100,000.

The factors which appear to have operated to reduce typhoid are in order:

1. Purification of the city water supply.

2. Houses in newly built up areas equipped with city water and sanitary plumbing.

3. Anti-typhoid vaccination.

SUMMARY GENERAL AND TYPHOID DEATH RATES

1891—1919 Inclusive

Year	Population	Total Deaths		Death Rate		% of Total Deaths Which are Typhoid
		All Causes	Typhoid Fever	All Causes per 1,000	Typhoid Fever per 100,000	
1890	105,436	....	....	....	....	....
1891	111,800	2,128	34	19	30.4	1.6
1892	118,200	1,985	54	16.8	45.6	2.7
1893	124,500	2,070	110	16.6	88.4	5.3
1894	130,900	1,834	56	14	42.7	3.1
1895	137,300	2,237	140	16.3	101.8	6.2
1896	143,700	2,057	75	14.3	52.1	3.7
1897	150,000	2,111	62	14.1	41.3	2.9
1898	156,400	2,251	55	14.4	35.2	2.4
1899	162,800	2,388	74	14.7	45.5	3.1
1900	169,164	2,626	74	15.5	43.8	2.8
1901	175,700	2.497	59	14.2	33.6	2.4
1902	182,200	2,492	76	13.7	41.7	3.
1903	188,600	2,790	93	14.8	49.2	3.3
1904	195,000	3,194	143	16.4	73.3	4.6
1905	201,300	3,081	71	15.2	35.3	2.3
1906	207,900	2,975	70	14.3	33.7	2.3
1907	214,400	3,163	62	14.8	28.9	2.
1908	220,700	2,907	60	13.2	27.2	2.1
1909	227,200	3,041	47	13.4	20.7	1.5
1910	233,650	4,039	67	17.3	28.6	1.7
1911	241,750	3,920	63	16.3	26.2	1.6
1912	248,700	3,739	45	15.1	18.2	1.2
1913	255,000	3,906	61	15.4	23.9	1.6
1914	262,500	4,136	69	15.7	26.3	1.7
1915	270,000	3,907	37	14.4	13.7	.9
1916	278,000	4,323	71	15.5	25.5	1.6
1917	286,250	4,587	31	16.0	10.8	.7
1918	295,000	5,273	19	17.8	6.4	.36
1919	304,000	4,137	14	13.6	4.6	.34

Average. 1891—1904 before filtration, 51.8.
Average. 1905—1919 after filtration, 22.0.

These figures as to typhoid death rates are presented as associate studies with the laboratory findings on the public water supply.

The data as to B. Coli and total bacterial content, as well as the discussions on the quality of the raw water and the ability to purify it, are presented and made on the basis that the water supply, as a source of water-borne diseases, was eliminated when the filter plant was placed in operation.

GENERAL SUMMARY.

The results of operation from a standpoint of quality of supply, and the studies in the cost of operation make it possible to summarize the experiences with a modified slow sand filtration plant briefly as follows:

The prime requirement of successful operation of slow sand filters is a proper condition of the sand layer. Operating in favor of this is the increased size of the particles applied in a pre-treated water, as well as reduced total suspended matter. Operating against the condition of the sand layer are two main factors. The first is the summer increase in micro-organisms which is becoming a far more important factor in water purification in the Central West than is generally recognized. This difficulty is also a means of interfering with satisfactory operation of rapid sand filters. The second is "air-binding." In slow sand filters during the winter months there may be a very considerable reduction of output due to the occlusion of air within the sand layer, commonly termed air-binding." In slow sand filters during the winter months minimum temperature the capacity for solution of oxygen is at its highest. Very small changes in temperature or physical condition seem to throw a portion of this out of solution and this is particularly manifested in filter sand layers where at times during the cold months a very material restriction to the actual flow capacity of the filter unit may be occasioned by the inclusion of air bubbles between the grains of sand. This may manifest itself in a spongy consistency of the sand layer quite comparable to quicksand when the water is drained off, and is also evidenced by small craters or rosettes, as it may be termed, of sand, scattered indiscriminately over the surface where the air has gathered in large particles and forced its way to the surface. This problem has been the source of very serious difficulties, notably in the case of the Wilmington, Del., plant, and represents at the present time one factor in the operation of all filtration plants, but notably slow sand units, likely to give difficulty during the cold weather.

The operation of slow sand filter plants, while it has extended over a great many years, has not been the subject of such careful study in this country as have the operations of mechanical filter plants. The best summary of the basic rules of slow sand filtration of water was made by George W. Fuller at the Lawrence Experiment Station at Lawrence, Mass., in 1894. These fundamentals may be briefly re-stated as follows:

1. Bacterial efficiency of slow sand filters increases with age, other conditions being equal.

2. New filter sand is quite unlike that taken from filters

which have been in operation for same time. The grains of the latter are covered with a sticky coating; in the case of grains situated at or just below the upper surface layer of sand this coating is so thick that the grains are considerably discolored. Here it is that the applied bacteria are detained in the largest numbers.

"3. In new filters, and in old filters which have been out of operation for a considerable period, normal bacterial results do not appear to be obtained until these films are formed.

"4. In old filters which are in regular operation, and which yield normal chemical and bacterial results, a marked deterioration in these results occurs when for any reason these is a well-defined mechanical disturbance of the main body of sand, whereby the continuity of the films is broken to a certain degree." * * *

"5. Low rates are undoubtedly safer than high rates; but, nevertheless, up to a certain limit the rate apparently exerts very little influence, and this limit is different for different filters and varies with other conditions in the case of the same filter." * * *

"6. With our present knowledge it may be stated that the factor which causes the effect of the rate of filtration upon bacterial efficiency to become practically nil, under normal conditions, is chiefly the age of the filter."

In the operation of the Indianapolis plant, the studies made during the fifteen years make it possible to add to these observations the following:

The pre-treatment by coagulant of a water supplied to slow sand filters results in the grouping together of the suspended particles in fairly large aggregates which substitute in a measure for the sticky coating of the surface layer. The bacterial content of a sand layer filtering pre-treated water is not so high in total numbers nor so active as in the case of a filter handling untreated influent.

The bacterial efficiency of filters operating in this fashion is less than that of filters operating with an untreated influent. The removal of organic material from the water to be filtered lessens the supply of material to be deposited in the filters, and at the same time interferes with certain biological processes which are more active in the plain type.

Slow sand filters operating with a pre-treated water are more susceptible to seasonal variations of bacterial flora, both in the influent water and in the sand layer, and may at times unload somewhat in the fashion of sewage filters. This unloading process has no relation to the quality of raw water, and with a sterilization treatment following is not apparent in the finished product.

Shutting off units and allowing them to stand for twenty-four to forty-eight hours does not seem to interfere with efficiency in production of bacterial reduction. Continuation of this, however, for a week or more seems to result in the deposition of material within the upper sand layer which materially reduces the production of the filter unit on the ensuing run.

Variations in depth of sand layer from eight to thirty inches have been allowed to exist on the local plant, and the results of operation indicate that the thinner layers give no less satisfactory bacterial purification. In point of ease of handling the filter unit, the thinner layer is preferable.

CONCLUSION.

The operation of the Indianapolis filtration plant was, in its earlier years, attended with some difficulty, which by the covering and dividing of the filters in 1905 and 1906 and the adoption of the preliminary coagulation and settling process in 1908, has been eliminated, with the result that water of excellent quality is being produced at a normal cost. The installation has justified itself. Also has the amount of technical control justified itself. In November, 1903, the Company established its laboratory, the operation of which has been continuous and increasing in volume. It has been the settled policy of the entire organization to leave nothing undone which would satisfy all persons concerned as to the quality of the supply. It is proper in this connection that appreciation should be expressed to the officers of the organization who have co-operated in all things looking toward the successful operation of the filtration system. It is also proper to express appreciation of the fine spirit of service of Mr. C. K. Calvert who, since 1908, has been the chemist at the filtration plant.

BOTTLED WATERS—BACTERIA PER CC. GROWING AT 20°

Date	Aquos	Auqos Tripure	Puro	Carters-burg	Waukesha	Crystal Spring	Tuckahoe	Mount Jackson	Alma-naris	Aquos Puro	Average	Average City Tap Water
1907–8	510	....	580	1,355	6,125	933	862	....	....	....	1,072	26
1908–9	1,264	....	637	1,128	12,500	1,838	3,573	....	....	....	2,027	46
1909–10	4,713	....	4,660	1,976	11,096	2,280	2,992	3,925	....	....	4,530	41
1910–11	1,862	....	80	3,394	5,396	2,412	714	4,737	....	....	2,865	19
1911	4	....	....	6,989	9,544	785	....	2,629	....	....	4,073	30
1912	723	....	....	1,698	4,850	904	....	705	....	....	1,750	54
1913	4,000	....	....	741	12,290	633	880	607	124	....	3,328	22
1914	32,161	....	....	2,115	9,982	....	355	396	936	....	7,658	22
1915	5,918	....	....	916	3,864	....	....	570	1,704	....	2,594	20
1916	339	....	....	1,265	6,723	....	....	927	523	1,095	1,812	30
1917	....	176	....	1,538	456	....	....	715	669	45	536	21
1918	....	52	....	1,524	863	....	....	427	....	86	648	34
1919	....	175	....	610	....	....	....	....	....	431	411	9
Average.	5,150	130	1,490	1,940	6,975	1,400	1,565	1,560	790	410	2,560	28

SUMMARY OF BACTERIA PER C. C. GROWING AT 20°

Year	Raw Water			Settled Water			Filter Effluent		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
1904	71,000	175	3,100	....	....	....	6,200	6	282
1905	157,000	150	5,384	....	....	....	1,925	1	51
1906	74,000	75	2,702	....	....	....	266	1	19
1907	30,000	100	1,537	....	....	....	353	3	26
1908	225,000	200	8,048	6,000	50	498	2,866	2	128
1909	150,000	50	4,200	12,000	10	738	1,700	2	78
1910	90,000	50	2,976	20,000	6	1,017	6,176	4	320
1911	45,000	40	1,976	8,000	5	792	1,080	2	102
1912	135,000	60	3,725	30,000	15	1,480	7,100	4	251
1913	30,000	35	1,446	5,000	10	324	354	3	52
1914	30,000	20	651	6,000	15	275	700	3	73
1915	50,000	100	1,838	9,000	20	849	600	4	75
1916	15,000	80	1,222	2,000	20	327	1,500	4	74
1917	70,000	60	4,147	10,000	40	1,126	3,000	2	124
1918	200,000	50	4,243	40,000	12	1,602	5,000	4	223
1919	50,000	150	2,290	9,000	40	836	1,600	4	126
For the Period.	225,000	20	3,134	40,000	5	854	7,100	1	120

SUMMARY OF BACTERIA PER C. C. GROWING AT 20°

Year	Filter Plant Effluent			Tap Water		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1904	6,200	6	282	24,000	4	1,224
1905	1,925	1	51	5,200	38	144
1906	266	1	19	1,983	3	52
1907	353	3	26	238	2	20
1908	2,866	2	128	377	7	47
1909	280	1	33	487	4	43
1910	1,800	0	36	666	1	30
1911	200	0	12	616	2	30
1912	2,000	0	33	2,136	1	54
1913	250	0	25	150	1	22
1914	200	0	17	158	2	22
1915	500	0	20	400	3	20
1916	150	0	9	300	2	30
1917	3,000	0	29	1,500	1	21
1918	2,400	0	40	2,100	0	34
1919	90	0	9	250	1	9
1904-09	6,200	1	34	2,136	2	100
1910-19	3,000	0	23	24,000	0	30

SUMMARY OF BACTERIA PER C. C. GROWING AT 37°

Year	Raw Water			Settled Water			Filter Effluent		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
1913	1,500	25	191	350	6	81	310	2	19
1914	5,000	20	174	400	10	76	190	2	21
1915	1,800	15	203	900	15	83	300	2	19
1916	3,500	20	255	700	10	86	80	3	18
1917	20,000	80	1,913	4,000	15	445	800	3	57
1918	34,000	50	1,946	11,500	15	456	1,500	3	57
1919	18,000	60	981	3,000	70	289	425	3	35
1913–19	34,000	15	868	11,500	6	227	1,500	2	33

SUMMARY OF BACTERIA PER C. C. GROWING AT 37°

Year	Filter Plant Effluent			Tap Water		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1912	100	0	12	157	0	22
1913	80	0	10	50	0	10
1914	75	1	10	150	2	16
1915	60	0	8	80	2	10
1916	20	0	5	250	1	17
1917	60	0	10	150	1	13
1918	160	1	10	180	1	13
1919	20	1	7	28	1	7
1912–19	160	0	10	250	0	14

RAW WATER

Bacteria per C. C. Growing at 20°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1904	....	....	....	....	....	....	....	....	1,840	650	560	9,350	3,100
1905	4,410	18,302	22,328	4,480	3,466	1,380	980	1,170	740	410	1,740	5,200	5,384
1906	8,387	3,712	10,647	4,425	482	752	771	565	300	190	992	1,205	2,702
1907	3,374	552	4,673	370	555	1,123	1,067	471	626	580	877	4,173	1,537
1908	6,250	22,570	35,500	9,667	14,467	3,422	705	732	524	567	1,263	911	8,048
1909	850	20,835	7,830	4,887	4,590	1,270	1,380	420	942	587	3,266	3,554	4,200
1910	18,920	6,215	5,030	260	870	900	580	200	237	360	240	1,900	2,976
1911	7,170	2,660	735	7,608	250	403	198	212	193	1,058	2,178	1,047	1,976
1912	3,302	19,026	12,546	4,320	1,550	700	1,249	219	187	255	500	726	3,725
1913	8,657	873	4,623	756	434	268	241	204	240	223	384	466	1,446
1914	661	671	1,963	3,092	212	167	155	106	63	114	106	503	651
1915	2,354	9,563	5,026	860	234	812	1,067	554	193	243	619	531	1,838
1916	5,742	2,460	1,745	434	514	1,265	160	194	230	227	277	1,416	1,222
1917	6,020	11,544	13,826	4,516	2,413	2,230	961	124	397	3,937	1,657	2,145	4,147
1918	3,580	28,635	5,215	2,450	745	357	268	720	860	641	1,153	6,288	4,243
1919	5,465	1,516	9,186	1,517	2,582	2,106	469	440	430	1,315	1,364	1,086	2,290
Avg.	5,676	9,942	9,391	3,309	2,224	1,143	683	422	500	710	1,073	2,531	3,134

SETTLED WATER

Bacteria per C. C. Growing at 20°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1908	....	22,500*	15,010*	486	801	354	409	....	....	....	450	490	498
1909	450	2,740	1,051	655	341	78	110	171	182	205	546	2,324	738
1910	3,856	1,785	4,770	125	135	135	120	150	90	160	180	700	1,017
1911	2,115	2,500	740	1,083	93	90	189	129	98	241	1,424	802	792
1912	2,373	7,282	4,769	1,654	331	130	103	63	70	201	167	604	1,480
1913	1,548	596	550	244	127	73	54	76	96	115	182	225	324
1914	467	608	923	455	108	66	7	66	33	51	65	383	275
1915	1,965	3,313	3,233	272	61	140	115	85	70	87	293	550	849
1916	911	688	506	222	69	168	106	149	101	79	141	787	327
1917	2,996	2,681	1,735	728	731	137	160	107	129	337	890	2,891	1,126
1918	3,030	10,030	1,103	321	244	127	108	406	165	195	604	2,876	1,602
1919	3,827	1,260	1,933	364	357	167	249	300	145	200	614	615	836
Avg.	2,140	3,044	1,938	551	283	139	150	155	107	170	463	1,104	854

*No coagulation. Not included in average.

FILTER EFFLUENT

Bacteria per C. C. Growing at 20°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1904	....	....	....	....	....	....	....	....	97	11	19	1,000	282
1905	161	71	175	15	11	6	8	11	5	2	100	49	51
1906	53	7	71	23	3	3	6	9	3	3	17	31	19
1907	50	9	76	7	13	13	10	7	9	7	10	107	26
1908	141	453	757	26	20	20	20	23	17	12	18	23	128
1909	26	120	35	21*	26	16	53	107	58	23	40	414	78
1910	1,304	1,807	315	17	29	35	45	23	24	21	27	212	320
1911	396	150	22	24	32	33	40	81	39	47	215	144	102
1912	555	1,226	863	94	31	45	29	34	35	22	16	59	251
1913	142	154	112	18	15	24	22	36	29	17	12	47	52
1914	153	169	207	32	29	45	49	39	12	14	12	120	73
1915	298	235	63	22	16	32	29	24	19	14	44	101	75
1916	186	102	63	21	23	15	24	29	18	38	78	285	74
1917	349	194	55	29	24	34	123	22	21	39	96	504	124
1918	625	1,148	176	33	21	72	194	72	56	16	129	137	223
1919	644	107	95	44	68	72	58	44	32	12	46	295	126
Avg.	339	397	206	28	24	31	47	37	30	19	55	221	120

*Hypochlorite of Lime first used April 9, 1909—Bacteria counts on sterilized water tabulated from Aug. 1st.

FILTER PLANT EFFLUENT

Bacteria per C. C. Growing at 20°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1904	....	....	....	....	....	....	....	....	97	11	19	1,000	282
1905	161	71	175	15	11	6	8	11	5	2	100	49	51
1906	53	7	71	23	3	3	6	9	3	3	17	31	19
1907	50	9	76	7	13	13	10	7	9	7	10	107	26
1908	141	154	162	26	20	20	20	23	17	12	18	23	53
1909	26	120	35	21	26	16	53	32	12	8	22	22	33
1910	340	6	6	2	2	5	7	5	6	7	8	38	36
1911	17	9	5	6	5	4	10	14	24	15	25	11	12
1912	51	250	15	7	7	11	8	8	9	11	13	6	33
1913	58	108	28	7	12	11	14	15	15	9	6	15	25
1914	15	19	18	5	11	18	15	14	6	6	7	65	17
1915	86	58	7	6	4	7	9	5	5	11	8	33	20
1916	33	14	4	5	7	5	7	6	5	7	6	14	9
1917	18	7	3	4	3	3	4	3	2	3	6	296	29
1918	70	351	4	3	3	9	5	9	5	4	12	4	40
1919	29	6	7	5	8	7	9	6	6	9	3	9	9
1904–09 Avg.	77	79	41	9	9	9	12	11	15	8	19	115	31
1910–19 Avg.	72	83	10	5	6	8	9	9	8	8	9	49	23

TAP WATER

Bacteria per C. C. Growing at 20°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1904	....	1,382	3,778	5,984	239	150	198	98	142	....	5	263	1,224
1905	286	471	437	28	47	41	65	89	79	76	47	61	144
1906	52	29	178	92	25	32	62	45	19	18	31	46	52
1907	31	10	55	6	10	14	15	9	13	9	12	56	20
1908	28	65	78	20	19	82	62	116	36	25	20	18	47
1909	21	104	32	23	41	57	88	17	13	23	55	42	43
1910	142	5	8	5	9	46	53	27	13	15	8	29	30
1911	13	10	7	7	7	90	52	96	33	26	22	6	30
1912	37	261	22	14	30	36	31	111	70	14	10	15	54
1913	42	48	25	12	14	27	20	23	15	12	9	16	22
1914	6	6	16	7	25	68	56	20	9	10	6	40	22
1915	28	53	9	13	14	12	17	15	14	12	20	31	20
1916	41	19	11	10	44	56	102	36	12	11	9	12	30
1917	14	5	4	4	5	5	10	8	6	9	4	172	21
1918	81	236	6	17	6	7	11	16	12	7	10	3	34
1919	25	8	8	4	5	15	11	9	7	4	3	7	9
1904–19 Avg.	56	170	292	390	34	46	53	46	31	18	17	51	100
1910–19	85	65	12	9	16	36	36	36	19	12	10	33	30

RAW WATER

Bacteria per C. C. Growing at 37°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1913	....	....	....	181	158	195	216	214	295	213	145	104	191
1914	87	196	414	557	142	146	137	108	70	102	38	96	174
1915	263	355	40	41	148	302	328	343	115	124	269	103	203
1916	427	165	260	106	140	433	186	233	231	141	82	659	255
1917	3,608	3,020	3,600	1,910	2,705	2,721	1,076	176	564	1,555	1,292	728	1,913
1918	1,581	9,795	4,759	927	356	366	293	437	878	469	452	3,022	1,946
1919	1,385	325	2,805	697	1,180	1,493	382	590	520	792	1,032	575	981
Avg.	1,225	2,309	1,980	631	690	808	374	300	382	485	473	755	868

SETTLED WATER

Bacteria per C. C. Growing at 37°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1913	....	....	....	56	55	83	51	93	152	87	80	76	81
1914	66	128	174	123	55	58	80	80	43	47	21	41	76
1915	186	130	26	20	34	68	80	68	40	42	142	160	83
1916	137	43	46	59	28	68	83	185	106	50	37	195	86
1917	1,160	643	362	274	651	203	216	263	220	247	308	792	445
1918	1,065	1,212	431	136	78	167	164	727	319	121	224	828	456
1919	587	114	256	165	173	181	217	556	217	164	508	324	289
Avg.	534	378	208	119	153	118	127	282	157	108	189	345	227

FILTER EFFLUENT

Bacteria per C. C. Growing at 37°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1913	....	....	....	9	10	14	18	34	48	14	12	9	19
1914	11	31	25	11	14	44	39	30	14	9	7	14	21
1915	62	26	11	9	10	18	13	22	13	9	13	23	19
1916	21	11	13	10	10	9	24	40	25	13	11	29	18
1917	136	102	23	10	34	61	107	26	30	45	23	84	57
1918	158	95	28	10	9	58	118	72	59	11	28	33	57
1919	64	16	18	9	16	57	56	81	40	12	19	37	5
Avg.	75	47	20	10	15	37	54	44	33	16	16	33	33

FILTER PLANT EFFLUENT

Bacteria per C. C. Growing at 37°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1912	16	25	23	14	9	7	8	8	14	11	5	7	12
1913	21	14	9	6	5	7	8	10	15	9	6	6	10
1914	9	10	11	6	6	19	13	12	7	5	5	12	10
1915	19	14	8	5	4	5	6	4	5	7	6	11	8
1916	8	4	7	4	4	4	3	5	3	5	5	11	5
1917	21	25	10	5	5	4	5	4	5	5	7	29	10
1918	35	22	13	6	4	8	5	8	6	4	7	5	10
1919	7	9	11	5	7	6	7	8	7	9	4	7	7
Avg.	19	18	13	7	6	9	8	8	9	8	6	13	10

TAP SAMPLES

Bacteria per C. C .Growing at 37°

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1912	22	35	26	14	12	21	27	28	53	15	6	11	22
1913	12	15	12	7	6	10	10	14	12	8	8	7	10
1914	9	10	10	6	11	54	44	16	10	7	5	8	16
1915	25	14	9	5	5	7	10	8	6	8	9	14	10
1916	11	6	8	6	10	29	72	22	7	7	8	15	17
1917	20	20	8	6	6	5	10	9	7	7	12	41	13
1918	41	30	11	12	5	11	8	14	10	5	8	5	13
1919	9	9	11	6	5	10	7	9	8	4	4	6	7
Avg.	19	17	12	8	8	18	24	15	14	8	8	13	1[illegible]

RAW WATER

Range of Bacteria Growing at 20°

From To	0–50	51–75	76–100	101–150	151–200	201–250	251–500	500–1,000	1,001–1,500	1,501–2,000	2,001–2,500	2,501–5,000	5,001–10,000	10,001–25,000	25,001–50,000	50,001–100,000	Over 100,000	Total Test Days
1904	....	....	....	....	4	5	29	26	8	1	1	3	2	3	4	1	0	87
1905	....	....	....	7	10	11	56	102	52	27	11	32	18	23	6	4	4	363
1906	....	2	21	17	30	19	80	67	32	25	8	26	17	10	5	4	0	363
1907	....	....	1	2	20	13	129	95	26	19	3	30	20	4	1	0	0	363
1908	....	....	....	....	4	4	60	82	29	37	8	37	19	18	16	12	4	330
1909	1	1	7	5	14	23	92	74	24	11	8	11	11	11	15	1	1	310
1910	3	1	17	38	43	18	75	44	3	5	11	24	15	6	5	4	0	312
1911	3	1	18	30	35	19	70	43	21	12	9	31	12	2	5	0	0	311
1912	....	1	21	27	26	9	65	71	16	6	4	24	15	10	6	4	1	306
1913	4	1	13	27	49	21	82	70	16	2	0	2	9	7	3	0	0	306
1914	13	20	53	56	30	10	39	57	13	3	0	2	1	3	1	0	0	301
1915	0	0	6	43	50	21	60	39	19	10	4	29	27	2	2	0	0	312
1916	0	0	21	31	63	24	56	32	17	14	3	33	7	4	0	0	0	305
1917	....	2	11	11	17	6	51	59	18	15	12	44	39	22	0	0	0	307
1918	3	9	6	13	10	18	74	69	21	13	7	24	15	16	8	1	2	309
1919	....	....	....	3	7	12	96	88	23	10	4	31	17	13	2	....	....	306
Total.	27	38	195	310	412	233	1,114	1,018	338	210	93	383	244	154	79	31	12	4,891
%	.6	.8	4.0	6.3	8.4	4.8	22.8	20.8	6.9	4.3	1.9	7.9	5.0	3.2	1.6	.6	.2	100

SETTLED WATER

Range of Bacteria Growing at 20°

From To	0–30	31–40	41–50	51–75	76–100	101–150	151–200	201–250	251–500	501–1,000	1,001–1,500	1,501–2,000	2,001–2,500	2,501–5,000	5,001–10,000	10,001–25,000	Over 25,000	Total Test Days
1908	....	....	2	2	13	9	16	2	39	33	2	2	0	2	2	0	0	124
1909	13	8	5	16	35	53	44	25	49	17	14	5	5	9	11	1	0	310
1910	10	5	15	35	43	58	31	10	13	17	5	5	3	22	10	2	0	284
1911	15	3	10	23	54	21	27	6	32	44	21	19	6	26	1	0	0	308
1912	13	12	16	19	59	16	17	4	36	40	14	7	5	16	8	2	6	290
1913	17	16	12	38	61	33	22	4	37	41	8	1	2	4	0	0	0	296
1914	30	39	14	41	45	15	7	2	41	47	6	0	0	0	1	0	0	288
1915	3	12	4	40	82	43	9	3	17	19	9	13	5	28	8	0	0	295
1916	15	13	16	24	59	34	23	12	38	49	12	2	0	0	0	0	0	297
1917	0	2	1	11	49	43	21	6	36	34	23	17	6	22	12	0	0	283
1918	1	6	16	21	41	33	20	13	50	40	19	12	6	7	6	7	4	302
1919	....	1	6	12	26	39	29	20	68	55	14	7	5	12	12	....	....	306
Total.	117	117	117	282	567	397	266	107	456	436	147	90	43	148	71	12	10	3,383
%	3.5	3.5	3.5	8.3	16.7	11.7	7.8	3.2	13.5	12.9	4.3	2.6	1.3	4.4	2.1	.4	.3	100

FILTER EFFLUENT

Range of Bacteria Growing at 20°.

From To	0–5	6-10	11–20	21–30	31–40	41–50	51–75	76–100	101–150	151–200	201–250	251–500	501–1,000	Over 1,000	Total Test Days
1904	4	29	23	7	3	4	1	0	2	2	0	2	4	3	84
1905	133	50	74	27	14	5	11	5	7	4	3	3	6	2	344
1906	197	74	46	11	8	4	6	3	2	2	3	5	2	0	363
1907	61	123	105	19	8	7	8	2	13	5	7	4	0	0	362
1908	6	42	109	49	24	7	14	15	9	6	6	15	19	9	330
1909	8	41	79	59	26	13	25	11	13	6	7	14	4	4	310
1910	4	29	78	36	32	15	18	10	13	6	3	17	20	32	313
1911	8	29	56	41	27	21	25	19	28	20	13	19	6	3	315
1912	1	20	84	41	16	21	29	14	18	10	11	21	8	19	313
1913	13	42	87	49	12	12	22	12	27	18	6	6	0	0	306
1914	9	31	63	39	28	21	27	25	24	13	9	17	2	0	308
1915	6	44	95	54	14	9	15	11	12	18	7	25	2	0	312
1916	7	31	96	41	18	10	23	28	19	18	3	8	3	1	306
1917	18	58	69	26	22	14	19	15	12	16	2	20	12	5	308
1918	7	37	64	24	23	20	22	20	20	20	9	22	6	15	309
1919	2	15	49	48	32	18	31	37	30	6	2	20	15	1	306
Total.	484	696	1,180	572	310	204	295	229	254	175	91	217	91	85	4,883
%	9.9	14.3	24.2	11.7	6.3	4.2	6.0	4.7	5.2	3.6	1.9	4.4	1.9	1.7	100

FILTER PLANT EFFLUENT

Range of Bacteria Growing at 20°.

From To	0–5	6–10	11–20	21–30	31–40	41–50	51–75	76–100	101–150	151–200	201–250	251–500	Over 500	Total Test Days
1904	4	29	23	7	3	4	1	0	2	2	0	2	7	84
1905	133	50	74	27	14	5	11	5	7	4	3	3	8	344
1906	197	74	46	11	8	4	6	3	2	2	3	5	2	363
1907	61	123	105	19	8	7	8	2	13	5	7	4	0	362
1908	6	43	112	50	27	10	13	17	14	11	6	14	1	324
1909	31	54	89	46	23	11	16	4	9	4	6	2	0	295
Total.	432	373	449	160	83	41	55	31	47	28	25	30	18	1,772
1910	177	75	31	5	0	4	5	2	3	1	2	2	5	312
1911	132	86	45	17	5	5	4	3	3	3	0	0	0	303
1912	127	91	52	5	6	1	6	11	2	0	0	2	4	307
1913	75	92	64	20	13	6	3	10	5	7	3	0	0	298
1914	103	113	48	9	7	4	4	10	5	2	0	0	0	305
1915	103	127	39	8	4	5	6	9	4	3	1	2	0	311
1916	160	97	29	7	3	1	0	7	2	0	0	0	0	306
1917	240	38	13	3	2	1	0	3	5	0	0	0	4	309
1918	200	67	18	4	4	1	1	....	1	....	....	3	6	305
1919	147	93	44	5	5	....	5	2	....	....	....	....	....	301
Total.	1,464	879	383	83	49	28	34	57	30	16	6	9	19	3,057
Total all yrs.	1,896	1,252	832	243	132	69	89	88	77	44	31	39	37	4,829
% '04–09	24.4	21.1	25.3	9.2	4.7	2.3	3.1	1.7	2.6	1.5	1.4	1.7	1	100
% '10–19	47.9	28.7	12.6	2.7	1.6	.9	1.1	1.9	1.0	.5	.2	.3	.6	100
% '04–19	39.3	26.0	17.3	5.0	2.7	1.4	1.8	1.8	1.6	.9	.6	.8	.8	100

TAP WATER

Range of Bacteria Growing at 20°

From To	0–5	6–10	11–20	21–30	31–40	41–50	51–75	76–100	101–150	151–200	201–250	251–500	501–1,000	Over 1,000	Total Test Days
1904	4	5	3	6	7	2	15	18	49	24	9	20	13	22	197
1905	0	7	24	42	38	31	59	21	35	14	3	6	11	5	296
1906	16	40	69	54	37	21	27	9	5	5	2	3	1	3	292
1907	31	106	111	22	10	6	7	9	7	1	1	....	....	....	311
1908	24	74	64	29	24	38	18	12	10	2	7	....	....	....	302
1909	9	47	100	57	24	6	20	14	18	4	3	6	....	....	308
1910	72	84	61	31	14	12	7	6	10	9	1	3	1	....	311
1911	64	81	75	23	13	11	13	10	7	2	3	5	2	....	309
1912	34	76	86	33	19	11	14	6	11	4	4	9	1	3	311
1913	28	78	104	47	18	10	6	6	7	....	....	....	....	....	304
1914	59	96	55	28	19	6	17	11	8	3	....	....	....	....	302
1915	22	129	93	20	11	6	13	7	2	....	1	1	....	....	305
1916	26	99	63	26	26	14	19	13	10	1	....	3	....	....	300
1917	161	92	26	3	1	1	2	1	3	....	....	3	1	1	295
1918	134	89	44	8	6	1	2	1	1	....	....	5	2	2	295
1919	123	130	37	10	1	1	1	1	....	....	1	....	....	....	305
Total.	807	1,233	1,015	439	268	177	240	145	183	69	35	64	32	36	4,743
%	17.0	26.0	21.5	9.3	5.6	3.7	5.1	3.0	3.9	1.4	.7	1.3	.7	.8	100

RAW WATER

Range of Bacteria per C. C. Growing at 37°

From To	0–5 6–10	11–20	21–30	31–40	41–50	51–75	76–100	101–150	151–200	201–250	251–500	501–1,000	1,001–1,500	1,501–2,000	2,001–2,500	2,501–5,000	5,001–10,000	10,001–25,000	25,001–50,000	50,001–100,000	Over 100,000	Total Test Days
1913	......	......	3	8	4	17	43	55	36	17	36	5	1	......	......	......	......	......	......	......	......	225
1914	......	5	10	18	17	32	77	74	27	8	15	13	1	......	1	1	......	......	......	......	......	299
1915	......	6	21	19	12	31	53	74	31	11	26	21	6	1	......	......	......	......	......	......	......	312
1916	......	5	41	18	18	29	43	40	39	18	52	24	2	1	1	3	......	......	......	......	......	304
1917	......	......	......	......	......	......	6	15	17	19	77	59	15	12	15	45	22	6	......	......	......	308
1918	......	......	......	......	1	6	12	21	32	25	81	51	10	12	7	24	13	11	3	......	......	309
1919	......	......	......	......	......	3	9	18	22	27	94	72	19	13	8	9	11	2	......	......	......	307
Total.	......	16	45	63	52	118	243	297	204	125	381	245	54	39	32	82	46	19	3	......	......	2,064
%	......	.8	2.2	3.1	2.5	5.7	11.8	14.4	9.9	6.0	18.5	11.9	2.6	1.9	1.5	4	2.2	.9	.1	......	......	100

SETTLED WATER

Range of Bacteria per C. C. Growing at 37°

From To	0–5	6–10	11–20	21–30	31–40	41–50	51–75	76–100	101–150	151–200	201–250	251–500	501–1,000	1,001–1,500	1,501–2,000	2,001–2,500	2,501–5,000	5,001–10,000	10,001–25,000	Over 25,000	Total Test Days
1913	......	2	11	12	22	12	44	75	23	6	4	2	......	......	......	......	......	......	......	......	213
1914	......	1	30	37	31	26	49	66	22	13	......	9	......	......	......	......	......	......	......	......	284
1915	......	1	43	46	46	29	42	47	16	6	2	12	3	......	......	......	......	......	......	......	293
1916	......	3	42	42	34	31	36	46	21	24	7	9	3	......	......	......	......	......	......	......	298
1917	......	......	1	......	2	2	6	37	45	40	26	64	38	10	9	1	5	......	......	......	286
1918	......	......	2	5	8	8	28	56	44	31	18	45	30	11	3	5	5	2	1	......	302
1919	......	1	......	......	3	3	20	56	61	50	18	58	27	4	4	1	1	......	......	......	307
Total.	......	8	129	142	146	111	225	383	232	170	75	199	101	25	16	7	11	2	1	......	1,983
%	......	.4	6.5	7.2	7.3	5.6	11.3	19.3	11.7	8.6	3.8	10.0	5.1	1.3	.8	.3	.6	.1	.1	......	100

FILTER EFFLUENT

Range of Bacteria per C. C. Growing at 37°

From To	0–5	6–10	11–20	21–30	31–40	41–50	51–75	76–100	101–150	151 200	201–250	251–500	501–1,000	Over 1,000	Total Test Days
1913	15	81	80	24	9	2	7	2	2	1	0	1	....	....	224
1914	14	92	108	26	20	12	25	7	2	1	....	....	....	....	307
1915	20	129	89	44	10	6	5	4	2	1	....	1	....	....	311
1916	20	97	132	25	8	9	9	4	1	....	....	....	....	....	305
1917	21	52	88	35	22	14	22	13	13	13	4	11	1	....	309
1918	22	65	72	40	26	20	20	11	8	7	5	7	5	1	309
1919	9	43	114	58	19	13	15	18	8	7	....	3	....	....	307
Total.	121	559	683	252	114	76	103	59	36	30	9	23	6	1	2,072
%	5.8	26.9	33	12.1	5.5	3.6	4.9	2.8	1.7	1.4	.4	1.1	.3	.5	100

FILTER PLANT EFFLUENT

Range of Bacteria Growing at 37°.

From To	0–5	6–10	11–20	21–30	31–40	41–50	51–75	76–100	Over 100	Total Test Days
1912	117	94	69	12	4	3	4	3	0	306
1913	118	97	49	8	7	2	6	1	0	288
1914	95	134	61	7	1	5	2	0	0	305
1915	148	110	44	6	1	1	1	0	0	311
1916	186	90	29	0	0	0	0	0	0	305
1917	149	75	48	21	8	4	4	0	0	309
1918	136	84	58	15	5	1	3	2	1	305
1919	110	130	64	....	....	....	....	....	....	304
Total.	1,059	814	422	69	26	16	20	6	1	2,433
%	43.5	33.5	17.3	2.9	1.1	.6	.8	.2	.1	100

TAP WATER

Range of Bacteria Showing at 37°.

From To	0–5	6–10	11–20	21–30	31–40	41–50	51–75	76–100	101–150	151–250	Over 250	Total Test Days
1912	36	77	103	37	24	10	12	3	4	1	0	307
1913	59	139	75	17	4	2	0	0	0	0	0	496
1914	44	148	54	17	11	8	11	5	3	0	0	301
1915	95	132	58	10	4	3	3	1	0	0	0	306
1916	62	142	52	11	7	4	7	8	3	2	0	298
1917	78	121	63	15	7	2	3	2	2	0	0	293
1918	102	105	61	10	16	3	3	2	2	1	....	305
1919	112	145	45	2	....	....	....	....	....	....	....	304
Total.	588	1,009	511	119	73	32	39	21	14	4	....	2,410
%	24.4	41.9	21.2	4.9	3.0	1.3	1.6	.9	.6	.2	....	100

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 C. C.

RAW WATER

Date	50	51–100	101–500	501–1,000	1,001–5,000	Over 5,000	Total Test Days	Average B. Coli per 100 c. c.	Bacteria per c. c. 37°
1915									
Jan.......	0	4	12	5	4	1	26	996	263
Feb......	0	1	11	4	6	2	24	1,746	355
March....	25	....	....	....	....	....	25	18	40
April.....	22	....	4	....	....	....	26	54	41
May......	7	2	10	3	3	1	26	1,237	148
June......	0	2	10	1	12	1	26	2,335	302
July......	0	2	8	3	13	1	27	3,218	328
Aug......	0	0	11	2	12	1	26	2,892	343
Sept......	....	12	13	1	....	....	26	204	115
Oct......	3	14	6	2	1	0	26	255	124
Nov......	2	6	9	4	4	1	26	1,425	269
Dec......	5	1	10	3	5	2	26	2,522	103
Total...	64	44	104	28	60	10	310	1,409	203
1916									
Jan.......	0	0	0	1	16	9	26	6,808	427
Feb......	7	2	5	1	8	1	24	1,473	165
March....	10	5	4	1	5	2	27	1,190	260
April.....	11	1	11	0	2	0	25	376	106
May......	3	5	18	0	1	0	27	299	140
June......	0	0	14	5	4	3	26	2,134	433
July......	0	7	14	3	1	0	25	388	186
Aug......	0	8	11	3	2	0	24	488	233
Sept......	5	10	4	4	2	0	25	392	231
Oct.......	6	16	4	0	0	0	26	1,000	141
Nov......	21	2	2	0	0	0	25	36	82
Dec......	3	7	9	3	2	0	24	393	659
Total...	66	63	96	21	43	15	304	1,173	255
1917									
Jan.......	1	....	....	7	....	18	26	17,577	3,608
Feb......	3	1	....	8	....	12	24	12,800	3,020
March....	3	4	....	5	....	15	27	15,756	3,600
April.....	1	5	....	7	....	12	25	12,300	1,910
May......	2	3	....	11	....	10	26	14,665	2,705
June......	5	4	....	16	....	1	26	1,015	2,721
July......	5	4	....	15	....	1	25	1,000	1,076
Aug.......	5	15	....	7	....	....	27	315	176
Sept......	1	10	....	12	....	1	24	960	564
Oct......	6	13	....	7	....	1	27	678	1,555
Nov......	7	10	....	7	....	2	26	1,077	1,292
Dec......	5	8	....	11	....	1	25	872	728
Total...	44	77	....	113	....	74	308	6,584	1,913
1918.									
Jan.......	....	7	....	17	....	3	27	4,948	1,581
Feb......	....	5	....	6	....	13	24	11,900	9,795
March....	....	....	....	8	....	18	26	23,400	4,759
April.....	2	5	7	5	4	3	26	1,822	927
May......	....	9	12	3	1	1	26	636	356
June......	3	1	10	9	2	....	25	639	366
July......	1	8	13	3	1	....	26	354	293
Aug......	1	3	19	4	....	....	27	354	437
Sept......	1	4	8	6	3	3	25	1,494	878
Oct......	14	4	5	3	1	....	27	321	469
Nov......	....	6	11	2	6	....	25	662	452
Dec......	2	3	3	....	8	9	25	5,135	3,022
Total...	24	55	88	66	26	50	309	4,305	1,946

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 C. C.

RAW WATER—Cont.

Date	50	51-100	101-500	501-1,000	1,001-5,000	Over 5,000	Total Test Days	Average B. Coli per 100 c. c.	Bacteria per c. c. 37°
1919.									
Jan.	....	1	7	2	9	7	26	2,857	1,385
Feb	5	2	13	4	....	....	24	323	325
March	2	4	1	2	10	6	25	4,916	2,805
April	3	8	8	3	2	2	26	2,738	697
May	....	1	12	3	6	3	25	1,800	1,180
June	1	....	8	8	5	1	23	1,112	1,493
July	3	6	16	1	....	....	26	221	382
Aug	1	6	18	....	1	....	26	303	590
Sept	3	7	11	3	2	....	26	425	520
Oct	2	3	13	3	4	2	27	2,333	792
Nov	2	....	1	6	8	8	25	13,628	1,032
Dec	2	1	3	1	15	4	26	4,085	575
Total	24	39	111	36	62	33	305	2,895	981

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 c. c.

SETTLED WATER

Date	10	11-50	51-100	101-500	501-1,000	Over 1,000	Total Test Days	Average B. Coli. per 100 c. c.	Bacteria per c. c. 37°
1915.									
Jan.	2	0	4	11	5	2	24	560	186
Feb	0	2	9	10	3	....	24	284	130
March	22	3	....	....	....	....	25	6	26
April	25	1	....	....	....	....	26	3	20
May	17	5	1	3	....	....	26	38	34
June	6	3	8	6	3	....	26	200	68
July	1	6	2	14	1	3	27	503	80
Aug	5	3	10	6	2	....	26	158	68
Sept	12	2	11	1	....	....	26	58	40
Oct	14	4	7	1	....	....	26	43	42
Nov	10	6	1	4	2	2	25	317	142
Dec	....	....	2	2	0	7	11	2,087	160
Total	114	35	55	58	16	14	292	355	83
1916.									
Jan.	....	....	2	13	9	2	26	585	137
Feb	2	7	2	4	1	0	16	133	43
March	10	10	0	7	0	0	27	73	46
April	14	6	1	2	2	0	25	90	59
May	18	9	0	0	0	0	27	11	28
June	8	7	8	3	0	0	26	61	68
July	11	2	9	1	1	1	25	207	83
Aug	17	0	5	1	0	1	24	150	185
Sept	20	2	3	0	0	0	25	15	106
Oct	22	3	0	0	0	0	25	6	50
Nov	21	2	0	0	0	0	23	44	37
Dec	6	5	7	4	....	....	22	80	195
Total	149	53	37	35	13	4	291	118	86

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 c. c.

SETTLED WATER—Cont.

Date	10	11–50	51–100	101–500	501–1,000	Over 1,000	Total Test Days	Average B. Coli per 100 c. c.	Bacteria per c. c. 37°
1917.									
Jan.......	1	....	3	....	13	10	27	7,530	1,160
Feb......	5	....	6	....	10	3	24	1,700	643
March....	5	....	11	....	8	2	26	1,078	362
April.....	9	....	9	....	6	1	25	678	274
May......	11	....	7	....	6	2	26	1,026	651
June......	10	....	13	....	3	0	26	168	203
July......	17	....	8	....	0	0	25	36	216
August...	25	....	2	....	0	0	27	13	263
Sept......	14	....	10	....	0	0	24	45	220
Oct......	21	....	6	....	0	0	27	23	247
Nov......	7	....	4	....	4	0	15	294	308
Dec.	2	....	5	....	6	0	13	500	792
Total.....	127	....	84	....	56	18	285	1,091	443
1918.									
Jan.......	3	....	5	....	11	1	20	1,071	1,065
Feb	1	....	5	....	7	11	24	3,180	1,212
March....	....	....	9	....	13	4	26	1,680	431
April.....	6	7	4	6	....	....	23	82	136
May.....	9	6	5	4	1	....	25	104	78
June......	5	15	4	....	....	....	24	34	167
July......	13	10	3	....	....	....	26	21	164
Aug......	15	10	....	....	....	....	25	16	727
Sept......	9	8	7	....	1	....	25	62	319
Oct......	15	6	4	1	1	....	27	52	121
Nov......	1	8	6	9	1	....	25	161	224
Dec......	2	3	4	5	5	6	25	1,296	828
Total...	79	73	56	25	40	22	295	647	456
1919.									
Jan.......	....	4	4	6	5	7	26	1,002	587
Feb......	4	14	3	3	....	....	24	59	114
March....	6	5	3	5	5	1	25	316	256
April.....	10	9	4	3	....	....	26	57	165
May......	....	11	1	11	2	....	25	233	173
June......	3	10	6	4	....	....	23	77	181
July......	20	6	....	....	....	....	26	11	217
Aug......	23	3	....	....	....	....	26	10	556
Sept......	12	11	1	2	....	....	26	40	217
Oct......	8	8	4	6	1	....	27	129	164
Nov......	....	....	....	7	4	14	25	3,996	508
Dec......	1	....	2	11	2	10	26	854	324
Total...	87	81	28	58	19	32	305	565	289

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 c. c.

FILTERED WATER

Date	0	1–2	3–5	6–10	11–25	26–50	Over 50	Total Test Days	Average B. Coli per100c. c.	Bacteria per c. c. 37°
1915.										
Jan.......	0	2	2	14	2	2	0	22	11	62
Feb......	3	2	3	4	0	5	7	24	37	26
March....	22	3	0	2	0	0	0	27	1	11
April.....	20	6	0	0	0	0	0	26	0.35	9
May......	10	8	2	4	1	1	0	26	4	10
June......	4	9	0	1	0	1	10	25	113	18
July......	0	2	2	9	10	4	0	27	20	13
Aug......	2	5	3	16	0	0	0	26	6	22
Sept......	1	15	3	6	1	0	0	26	4.5	13
Oct......	8	14	2	2	0	0	0	26	2	9
Nov......	2	9	7	0	2	3	3	26	31	13
Dec......	0	0	1	10	5	3	7	26	95	23
Total...	72	75	25	68	21	19	27	307	27	19
1916.										
Jan.......	0	0	0	3	5	7	11	26	93	21
Feb......	1	2	3	16	1	1	....	24	8	11
March ...	10	6	3	6	2	0	....	27	4	13
April.....	9	9	2	2	2	1	....	25	4	10
May......	13	9	4	1	0	0	....	27	1.4	10
June......	16	7	0	2	1	0	....	26	2	9
July......	7	9	3	4	1	1	....	25	6	24
Aug......	10	4	2	6	1	2	....	25	6.6	40
Sept......	11	6	2	6	0	0	....	25	3	25
Oct.......	16	7	3	0	0	0	....	26	15	13
Nov......	12	6	3	4	0	0	0	25	2.6	11
Dec......	4	4	4	7	2	3	1	25	12	29
Total...	109	69	29	57	15	15	12	306	12	18
1917.										
Jan.......	3	....	....	2	....	9	10	24	1,580	136
Feb......	2	....	....	6	....	9	7	24	332	102
March....	13	....	....	12	....	2	0	27	12	23
April.....	13	....	....	9	....	2	0	24	12	10
May......	13	....	....	8	....	4	1	26	56	34
June......	16	....	....	8	....	2	....	26	10	61
July......	12	....	....	11	....	2	....	25	12	107
Aug......	18	....	....	9	....	0	....	27	2.4	26
Sept......	17	....	....	7	....	0	....	24	1.8	30
Oct......	17	....	....	9	....	1	....	27	5	45
Nov......	8	....	....	14	....	4	....	26	20	23
Dec......	5	....	....	9	....	7	4	25	192	84
Total...	137	....	....	104	....	42	22	305	186	57
1918.										
Jan.......	5	....	....	4	....	....	18	27	135	158
Feb......	7	....	....	3	....	....	14	24	135	95
March....	7	....	....	10	....	....	9	26	108	28
April.....	8	6	4	7	1	....	....	26	4	10
May......	10	7	7	2	....	....	....	26	2	9
June......	11	8	5	....	1	....	....	25	2	58
July......	10	5	6	....	....	....	....	21	1	118
Aug......	9	10	7	1	....	....	....	27	2	72
Sept......	2	6	9	3	1	4	....	25	9	59
Oct.......	16	8	2	1	....	....	....	27	1	11
Nov......	3	2	....	7	6	7	....	25	17	28
Dec......	2	2	2	3	3	9	4	25	29	33
Total...	90	54	42	41	12	20	45	304	38	57

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 c. c.

FILTERED WATER—Cont.

Date	0	1–2	3–5	6–10	11–25	26–50	Over 50	Total Test Days	Average B. Coli per100c. c.	Bacteria per c. c. 37°
1919.										
Jan.	....	....	....	5	1	8	12	26	127	64
Feb.	3	8	8	4	1	....	....	24	4	16
March	3	8	4	2	3	4	1	25	11	18
April	9	8	8	....	....	1	....	26	2.8	9
May	7	4	6	4	4	....	....	25	5.6	16
June	4	10	1	4	3	....	1	23	9	57
July	15	7	2	2	....	....	....	26	1	56
Aug.	15	7	4	....	....	....	....	26	.8	81
Sept.	4	8	6	6	1	....	1	26	6	40
Oct.	12	8	3	4	....	....	....	27	2.1	12
Nov.	1	....	....	2	7	9	6	25	66	19
Dec.	1	....	....	1	1	2	21	26	191	37
Total	74	68	42	34	21	24	42	305	35.5	35

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 c. c.

FILTER PLANT EFFLUENT

Date	0	1–2	3–5	6–10	Over 10	Total Test Days	B. Coli per 100 c. c.	Bacteria per c. c. 37°
1915.								
Jan.	11	10	2	....	....	23	1.2	19
Feb.	19	3	1	1	....	24	0.6	14
March	26	1	0	....	....	27	0.04	8
April	23	3	....	....	....	26	0.23	5
May	21	4	1	....	....	26	0.4	4
June	17	8	1	....	....	26	0.7	5
July	10	7	1	4	3	25	5.0	6
Aug.	12	13	1	....	....	26	1.0	4
Sept.	18	7	1	....	....	26	0.6	5
Oct.	12	10	2	2	....	26	1.7	7
Nov.	15	9	2	....	....	26	1.0	6
Dec.	10	5	5	4	2	26	4.5	11
Total	194	80	17	11	5	307	1.4	8
1916								
Jan.	16	5	1	2	2	26	4.2	8
Feb.	21	2	0	0	1	24	1	4
March	26	1	0	0	0	27	0.07	7
April	25	0	0	0	0	25	0.0	4
May	22	5	0	0	0	27	0.4	4
June	25	1	0	0	0	26	0.08	4
July	21	3	0	1	0	25	0.6	3
Aug.	19	4	0	2	0	25	0.9	5
Sept.	26	0	0	0	0	26	0.0	3
Oct.	23	1	2	0	0	26	0.4	5
Nov.	24	1	0	0	0	25	0.04	5
Dec.	25	1	0	0	0	26	0.04	11
Total	273	24	3	5	3	308	0.64	5

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 c. c.

FILTER PLANT EFFLUENT—Cont.

Date	0	1–2	3–5	6–10	Over 10	Total Test Days	B. Coli per 100 c. c.	Bacteria per c. c. 37°
1917.								
Jan.......	11	10	3	3	0	27	2	21
Feb......	19	4	1	0	0	24	.5	25
March....	18	6	2	1	0	27	.9	10
April......	21	4	0	0	0	25	.2	5
May......	22	4	0	0	0	26	1.5	5
June......	21	5	0	0	0	26	.3	4
July......	21	4	0	0	0	25	.24	5
Aug. ..	22	5	1	0	0	28	.3	4
Sept.....	20	3	1	0	0	24	.25	5
Oct......	20	6	1	0	0	27	.4	5
Nov......	18	8	1	0	0	27	.6	7
Dec......	5	6	1	13	0	25	5.	29
Total...	218	65	11	17	0	311	1.01	10
1918								
Jan.......	5	7	5	10	....	27	4	35
Feb......	10	7	3	4	....	24	2	22
March....	16	6	4	....	....	26	1.1	13
April.....	10	12	4	....	....	26	1.3	6
May......	24	2	....	....	....	26	.1	4
June......	23	2	....	....	....	25	.12	8
July......	23	3	....	....	....	26	.1	5
Aug......	25	....	....	....	....	25	0	8
Sept......	19	5	1	....	....	25	.3	6
Oct......	20	7	....	....	....	27	.3	4
Nov......	22	2	....	1	....	25	.4	7
Dec......	19	4	2	....	....	25	.6	5
Total...	216	57	19	15	....	307	.86	10
1919.								
Jan.......	19	7	....	....	....	26	.3	7
Feb......	22	2	....	....	....	24	.12	9
March....	24	1	....	....	....	25	.16	11
April.....	26	....	....	....	....	26	0	5
May......	19	6	....	....	....	25	.3	7
June......	17	3	1	1	....	22	.7	6
July......	20	6	....	....	....	26	.3	7
Aug......	24	2	....	....	....	26	.1	8
Sept......	20	5	1	....	....	26	.5	7
Oct......	16	9	2	....	....	27	.7	9
Nov......	20	4	....	1	....	25	.4	4
Dec......	18	4	2	2	....	26	.9	7
Total...	245	49	6	4	....	304	.37	7

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 c. c.

TAP WATER

Date	0	1–2	3–5	6–10	Over 10	Total Test Days	B. Coli per 100 c. c.	Bacteria per c. c. 37°
1915.								
Jan.......	14	4	1	3	....	22	1.4	25
Feb......	17	7	....	....	....	24	0.5	14
March....	26	....	....	....	....	26	0.0	9
April.....	24	2	....	....	....	26	.12	5
May......	23	1	....	1	....	25	.32	5
June......	14	6	3	3	....	26	1.7	7
July......	3	7	4	8	4	26	7	10
Aug......	1	6	6	8	4	25	8	8
Sept......	12	8	3	2	....	25	1.9	6
Oct......	3	18	1	2	2	26	3.8	8
Nov......	2	8	5	7	4	26	6	9
Dec......	6	4	3	11	2	26	7	14
Total...	145	71	26	45	16	303	3.1	10
1916.								
Jan.......	6	9	2	8	1	26	4.5	11
Feb......	20	1	2	1	....	24	0.7	6
March....	24	3	0	0	....	27	0.2	8
April.....	22	2	0	1	....	25	0.5	6
May......	7	4	2	6	7	26	11	10
June......	8	7	2	7	2	26	5	29
July......	11	10	1	3	....	25	2	72
Aug......	9	5	1	4	2	24	4.8	22
Sept......	13	9	4	0	....	24	1.1	7
Oct......	19	6	2	0	....	26	0.6	7
Nov......	19	3	1	0	....	23	0.7	8
Dec......	23	2	0	0	1	25	0.16	15
Total...	181	61	16	30	13	301	2.6	17
1917.								
Jan.......	21	....	0	5	0	26	1.9	20
Feb......	21	....	2	1	0	24	.75	20
March....	21	....	2	2	0	25	.7	8
April.....	18	....	4	0	0	22	.7	6
May......	25	....	1	0	0	26	.15	6
June......	22	....	2	2	0	26	1.1	5
July......	19	....	2	4	0	25	3.4	10
Aug......	12	....	11	4	0	27	3.1	9
Sept......	12	....	7	5	0	24	3.2	7
Oct. ..	11	5	5	4	0	25	3	7
Nov......	14	3	3	1	0	21	1.3	12
Dec......	15	0	0	9	0	24	4	41
Total...	211	8	39	37	0	295	1.94	13
1918.								
Jan.......	17	....	....	8	1	26	7	41
Feb......	18	....	....	3	1	22	5	30
March....	22	1	....	3	....	26	1.2	11
April.....	10	13	2	1	....	26	1.3	12
May......	12	11	1	....	....	24	.7	5
June......	5	18	1	....	1	25	2.4	11
July......	11	10	1	1	3	26	5	8
Aug......	13	9	5	....	....	27	1	14
Sept......	4	6	9	1	5	25	9	10
Oct......	17	9	....	....	....	26	.4	5
Nov......	19	4	1	1	....	25	.7	8
Dec......	21	4	....	....	....	25	.2	5
Total...	169	85	20	18	11	303	2.9	13

BACILLUS COLI COMMUNIS

Number of days on which there occurred various numbers per 100 c. c

TAP WATER—Cont.

Date	0	1–2	3–5	6–10	Over 10	Total Test Days	B. Coli per 100 c. c.	Bacteria per c. c. 37°
1919.								
Jan.......	16	9	....	....	....	25	.4	9
Feb......	22	2	....	....	....	24	.08	9
March....	20	4	....	1	....	25	.6	11
April.....	22	4	....	....	....	26	.2	6
May......	22	2	1	....	....	25	.24	5
June......	16	5	1	....	....	22	.5	10
July......	22	4	....	....	....	26	.2	7
Aug......	21	4	1	....	....	26	.3	9
Sept......	8	12	5	....	....	25	1	8
Oct......	7	14	6	....	....	27	1.6	4
Nov......	17	3	2	1	....	23	.8	4
Dec......	18	8	....	....	....	26	.3	6
Total...	211	71	16	2	....	300	.52	7

BACILLUS COLI COMMUNIS

Five Year Totals

Number of days on which there occurred various numbers per 100 C. C.

RAW WATER

Date	50	51–100	101–500	501–1,000	1,001–5,000	Over 5,000	Total Test Days	Average B. Coli per 100 c. c.	Bacteria per c. c. 37°
1915	64	44	104	28	60	10	310	1,409	203
1916	66	63	96	21	43	15	304	1,173	255
1917	44	77	....	113	....	74	308	6,584	1,913
1918	24	55	88	66	26	50	309	4,305	1,946
1919	24	39	111	36	62	33	305	2,895	981
Total.	222	278	399	264	191	182	1,536	....	....
%	14.5	18.1	26.0	17.1	12.4	11.9	....	....	....
Average.	44	55	100	53	48	36	307	....	....

SETTLED WATER

Date	10	11–50	51–100	101–500	501–1,000	Over 1,000	Total Test Days	Average B. Coli per 100 c. c.	Bacteria per c. c. 37°
1915	114	35	55	58	16	14	292	355	83
1916	149	53	37	35	13	4	291	118	86
1917	127	....	84	....	56	18	285	1,091	443
1918	79	73	56	25	40	22	295	647	456
1919	87	81	28	58	19	32	305	565	289
Total.	556	242	260	176	144	90	1,468	....	....
%	37.9	16.5	17.7	12.0	9.8	6.1	....	....	....
Average.	111	60	52	44	29	18	293	....	....

BACILLUS COLI COMMUNIS

Five Year Totals

Number of days on which there occurred various numbers per 100 c. c.

Filtered Water

Date	0	1–2	3–5	6–10	11–25	26–50	Over 50	Total Test Days	Average B. Coli per100c. c.	Bacteria per c. c. 37°
1915	72	75	25	68	21	19	27	307	27	19
1916	109	69	29	57	15	15	12	306	12	18
1917	137	....	....	104	....	42	22	305	186	57
1918	90	54	42	41	12	20	45	304	38	57
1919	74	68	42	34	21	24	42	305	35.5	35
Total.	482	266	138	304	69	120	148	1,527	....	....
%	31.6	17.4	9.0	19.9	4.5	7.9	9.7	....	....	....
Average.	96	66	34	61	17	24	29	305	....	....

Filter Plant Effluent

Date	0	1–2	3–5	6–10	Over 10	Total Test Days	Average B. Coli per 100 c. c.	Bacteria per c. c. 37°
1915	194	80	17	11	5	307	1.4	8
1916	273	24	3	5	3	308	0.64	5
1917	218	65	11	17	0	311	1.01	29
1918	216	57	19	15	0	307	0.86	10
1919	245	49	6	4	0	304	0.37	7
Total.	1,146	275	56	52	8	1,537	....	....
%	74.6	17.9	3.6	3.4	.5	....	....	....
Average.	229	55	11	10	1	307	....	....

Tap Water

Date	0	1–2	3–5	6–10	Over 10	Total Test Days	Average B. Coli per 100 c. c.	Bacteria per c. c. 37°
1915	145	71	26	45	16	303	3.1	10
1916	181	61	16	30	13	301	2.6	17
1917	211	8	39	37	0	295	1.94	13
1918	169	85	20	8	11	303	2.9	13
1919	211	71	16	2	0	300	0.52	7
Total.	917	306	117	122	40	1,502	....	....
%	61.0	20.4	7.8	8.1	2.7	....	....	....
Average.	183	63	23	24	8	300	....	....

WATER WORKS STATISTICS FOR THE YEAR 1920.

INDIANAPOLIS WATER COMPANY, INDIANAPOLIS, INDIANA.

Population of Indianapolis January 1, 1920.................. 314,194
Total estimated population supplied......................... 252,000

Date of original construction, 1870.
By whom owned, Indianapolis Water Company.

C. H. Geist, President.
C. L. Kirk, Vice-President and General Manager.
F. C. Jordan, Secretary.
E. C. Leible, Treasurer.

Source of supply, White River and deep wells.
Emergency supply from Fall Creek.

Water flows from White River near Broad Ripple, a town about eight miles north of the center of the city of Indianapolis, through a canal owned by the Water Company to the Filter Plant, where it flows through a Sedimentation Basin and thence through six slow sand filters. The slow sand filters have a daily capacity of 36 million gallons, the average daily yield for 1920 being 24.7 million gallons. The filtered water after being chlorinated flows to the pump well at the main station of the Indianapolis Water Company, known as the Riverside Station, and to a reservoir at this station having a capacity of 5½ million gallons. From the reservoir water flows by gravity to another station known as the Washington Station, where all the pumping is done by hydraulic power furnished by the Canal. The flow from Broad Ripple to and through the Filter Plant, thence to the reservoir at the Riverside Station and to the Washington Station is entirely by gravity.

The Filter Plant is located near Fall Creek and the pumping station at the Filter Plant is provided with low lift pumps in order to obtain an emergency supply from Fall Creek in the event of any interruption of the flow of the water through the Canal caused by a break or on account of improvements which are made along the Canal necessitating such interruption.

At the Riverside Station there are 43 deep wells with a capacity of from 18 to 22 million gallons daily; 18 of these wells are operated by air pressure from the central pumping station. The others are provided with electrically driven centrifugal pumps.

The eastern portion of the city, which is approximately 100 feet higher in elevation than the main part of the city, is supplied from the Fall Creek Station, which obtains its supply from 12 deep wells with a capacity of 6,200,000 gallons daily.

In addition to the two main sources of supply the Water Company owns a small station near Broad Ripple with a capacity of one million gallons. The supply is obtained from a deep well.

All wells are from 330 to 350 feet deep and have been drilled through rock. The well supply is practically sterile.

The Water Company maintains a well-equipped laboratory at the filter plant for the chemical and bacteriological examination of water. Samples are collected daily from all parts of the purification, pumping and distribution systems, and determinations made for the total number of bacteria and B. Coli in each sample. About twenty thousand bacterial counts and fifty thousand B. Coli estimations are made yearly.

(1) *Pumping:*

Riverside Station

	Capacity
One Hamilton Rarig Vertical Triple Expansion High Duty Pumping Engine	30 m. g. d.
One Snow Vertical Triple Expansion High Duty Pumping Engine	20 m. g. d.
One DeLaval Steam Turbine Driven Centrifugal Pump	30 m. g. d.
One DeLaval Steam Turbine Driven Centrifugal Pump	7½ m. g. d.
One DeLaval Steam Turbine Driven Centriugal Pump	6 m. g. d.
Total capacity at the Riverside Station for fire service	93½ m. g. d.

For domestic service the capacity is over 100 m. g. d.

Fall Creek Station

One Allis-Chalmers Horizontal Cross Compound Pumping Engine	6 m. g. d.
One DeLaval Steam Turbine Driven Centrifugal Pump	6 m. g. d.
Total	12 m. g. d.

Washington Street Station

Three Water Turbines operating DeLaval Centrifugal Multi-Stage Pumps, with a capacity of	14½ m. g. d.

Broad Ripple Station

One DeLaval Centrifugal Pump	1 m. g. d.

Supplementary pumping is done for the Fall Creek Station by Booster Pumps at two stations, with a capacity of 6 m. g. at one sta-

tion and 12 m. g. at the other. These pumps are DeLaval Centrifugal Pumps, electrically driven.

(2) *Description of Coal Used:*

Indiana Coal—Mine Run and Screenings.
The Riverside Station is provided with coal crushing machinery.
Percentage of Ash varies from 10 to 20%.
Coal consumed during year 1920, approximately 15,000 tons.
Total Pumpage for the year 1920, 11,037,902,000 gallons.

Total fixed capital, or value of property and plants, as shown by books of the Indianapolis Water Company as of December, 1920		$11,694,476.56
Capitalization—		
Funded debt:		
General Mortgage 5% Bonds	$2,359,000	
First and Refunding 4½% Bonds	3,711,000	
Total funded debt		$6,070,000.00
Capital Stock common	$5,000,000	
Capital Stock preferred 7%	295,000	
Total Capital Stock		5,295,000.00
Total Capitalization		$11,365,000.00

Consumption—1920

1. Estimated total population of district at date, 314,914.
2. Estimated total population supplied by the Indianapolis Water Company, 252,000.
3. Total number of gallons consumed for year, 11,037,902,000.
4. Percentage of consumption metered (estimated), 54%.
5. Average daily consumption in gallons, 30,159,000.
6. Gallons per day to each inhabitant, 87.
7. Gallons per day to each consumer, 120.
8. Gallons per day to each tap, 653.

Distribution

1. Kind of pipe used, cast iron.
2. Sizes, 4-inch to 40-inch.
(All new mains are 6-inch in diameter or larger.)
3. Extensions made in 1920, 60,000 feet.
4. Discontinued, none.
5. Total now in use, 450 miles.
9. Fire hydrants added in 1920, 87.
10. Number of public hydrants now in use, 3,763.
11. Gate valves added in 1920, 92.
12. Number now in use, 3,689.
15. Range of pressure on mains at center of city—
Domestic service, 45 to 50 lbs.
Fire pressure service, 85 to 95 lbs.

Services

16. Kind of pipe—
    Lead, ⅝-inch to 1½-inch.
    Byers W. I. pipe, 1½-inch to 3-inch.
    Cast iron, 3-inch to 8-inch.
17. Sizes, ⅝-inch to 8-inch.
21. Services added in 1920, 1,933.
22. Number of services now in use, 46,165.
25. Meters added in 1920, 466.
26. Meters now in use, 6,325.